Fuelling the Dragon: A Geopolitical Economy of Natural Gas Transition in China

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Chun Kai Leung

Abstract

To tackle its coal-induced air pollution and carbon mission problems, the Chinese government has sought to increase the share of natural gas in its fuel mix to 10 percent by 2020. The gasification of the fuel mix requires the gasification of the country's energy supply chain, which implies transitions in infrastructures, actors and institutions throughout the chain. This dissertation adopts the global production networks (GPN) approach to evaluate how this form of energy transition will unfold functionally, organisationally, institutionally and politically in and across space. Specifically, it assesses the relational landscape of China's energy governance, and its implications for gas acquisition, distribution and consumption. It finds: (i) the governments, national oil companies and Chinese Communist Party does not behave like a coherent monolith; instead a range of state actors and institutions have defined the structure of China's gas production network; (ii) China's state-led expansion of gas infrastructure is surprisingly effective despite the fragmented governance structure; (iii) national oil companies are seeking further vertical integration at the expense of the prospects of independent downstream players; (iv) China's gas extraction, import, distribution and consumption can only be understood in relation to one another; (v) any 'strategic coupling' between international oil companies and China's regional gas assets and institutions is conditional, and the window of opportunity is wider in the unconventional gas extraction and downstream distribution; and (vi) future development of gas consumption is institutionally uncertain. This research also, via the case of the gasification in China, demonstrates the utility of GPN approach for understanding energy transition.

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List of Acronyms

GDP	Gross domestic product
ANT	Actor-network analysis
ASEAN	Association of Southeast Asian Nations
Bcm	Billion cubic metre
CBEX	China Beijing Equity Exchange
CBM	Coalbed methane
CCP	Chinese Communist Party
CDB	China Development Bank
CDM	Clean Development Mechanism
CEEP	Center for Energy and Environmental Policy
CER	Certified Emission Reduction
CHP	Combined heat and power generation
CMM	Coal mine methane
CNG	Compressed natural gas
CNOOC	China National Offshore Oil Corporation
CNPC	China National Petroleum Corporation
CPPB	China Petroleum Pipeline Bureau
CUCBM	China United Coalbed Methane Corporation
E&P	Exploration & production
EBL	Energy-backed loan
EIA	Energy Information Administration
ESPGD	Energy Saving Power Generation Dispatching Measures
EU	European Union
FYP	Five-year Plan
GCC	Global commodity chains
GHG	Greenhouse gases
GPE	Geographical political economy
GPN	Global production networks
GVC	Global value chains
IEA	International Energy Agency
IMF	International Monetary Fund
IOC	International oil company
IPO	Initial public offering
JMC	Joint Management Committee
JV	Joint venture
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LSAW	Longitudinal Submerged Arc Welded
LULU	Locally-unwanted land use
MAF	Ministry of Foreign Affairs
MEP	Ministry of Environmental Protection
MLP	Multi-level perspective
MLR	Ministry of Land and Resources
MMBtu	Million British Thermal Units
MOC	Ministry of Commerce

Mtce	Million tonnes of coal equivalent
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NEC	National Energy Commission
NELG	National Energy Leading Group
NGO	Non-governmental organisation
NGV	Natural gas vehicle
NOC	National oil company
OFS	Oilfield Service
PSC	Production-sharing contract
RMB	Renminbi
SASAS	State Asset Supervisory and Administration Commission
SCO	Shanghai Cooperation Organisation
SEO	State Energy Office
SEZ	Special Economic Zone
Sinopec	China Petroleum & Chemical Corporation
SOE	State-owned enterprise
SSAW	Spiral Submerged Arc Welded
SUAEE	Shanghai United Assets and Equity Exchange
Tcm	Trillion cubic metre
UK	United Kingdom
UN	United Nations
US	United States
VAT	Value-added tax
WEGP	West-east Gas Pipeline
WGI	World Governance Indicator
WTO	World Trade Organisation
ZPGC	Zhuhai Pipeline Gas Company

Declaration

I confirm that no part of the material presented in this thesis has previously been submitted by me or any other person for a degree in this or any university. Where relevant, material from the work of others has been acknowledged.

Statement of Copyright

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For any errors or inadequacies that may remain in this work, the responsibility is, of course, entirely on my own.

Chapter 1 Introduction

1.1. Background

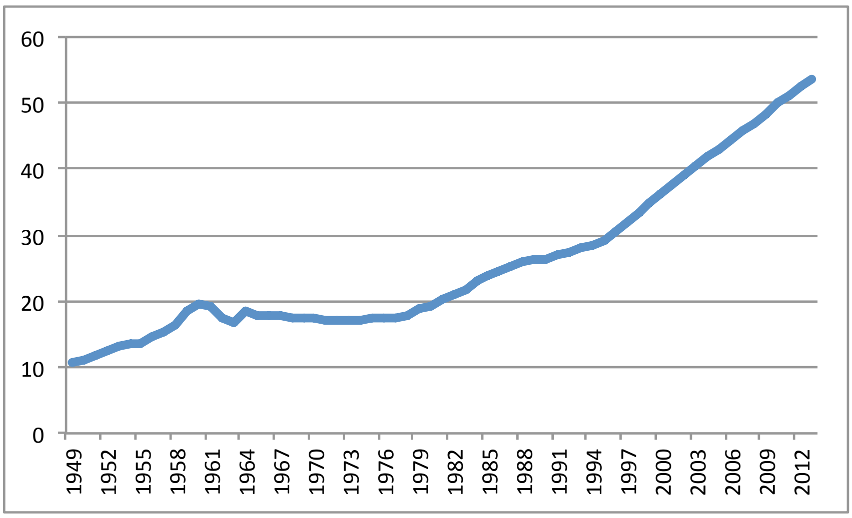
Asked by George W. Bush what would keep him up at night, former President Hu Jintao said that his biggest concern was creating 25 million new jobs a year (Yergin 2011). Although China overtook Japan and became the world's second largest economy in 2010, the regime realises that it is still vital for the country to maintain economic growth, create enough jobs for the graduates and rural migrant workers every year, and continue to increase the personal incomes of its citizens. Failure to achieve these unsettles the already fragile social stability, as China is still essentially a developing country: In 2012, China ranked the 101st in terms of Human Development Index (HDI), falling behind numerous developing countries, such as Columbia (91st), Bosnia and Herzegovina (81st), Venezuela (71st), Mexico (61st) and Uruguay (51st) (United Nations Development Programme 2013).

Development requires uninterrupted supplies of energy. The Preface of China's Energy Policy 2012, also known as the "energy white paper", officially claims that a "thriving energy industry provides a guarantee for the country to reduce poverty, improve the people's livelihood and maintain long-term, steady and rapid economic development" (Chinese Government 2012). China's primary energy consumption has grown significantly faster since 2002-2003 (Figure 1.1). From 2005 to 2010, China's demand for energy grew staggeringly by 73 percent and the country has become the world's largest energy consumer. This unexpected pace of energy consumption growth perplexed many international observers, including the US's Energy Information Administration, which predicted in 2006 that China would not overtake US energy consumption before 2030 (Kong 2011).

Energy security, however, is not the only consideration when Chinese leaders are drafting energy policy. The Chinese government understands that energy security is not the ultimate objective per se, but is a means, among others, to maintaining the political legitimacy of the regime and the Chinese Communist Party. While ideology or communism no longer function as a source of legitimacy, there is an unwritten social contract between the Party and the people it governs that, as long as the Party is capable of improving the quality of life of the people continuously, it does not need to share its power (Leung 2011). Energy security is vital to maintain economic growth, but if the way the energy economy operates causes environmental damage to the extent that it deteriorates the quality of life, it defeats its purpose. In other words, the problem of energy security is not only about "what to protect" and "from what risks", but also "how to protect" (Leung et al. 2014). Bradshaw (2013) rightly captures the "how to protect" question and holds that every country is facing their own "energy dilemma": how to ensure energy security in an environmentally acceptable manner.

Against this backdrop, China's 12th Five-year Plan (FYP, 2011-2015) demands that both central and local economic planners to engage in low-carbon energy transition, which consists of a shift from fossil fuels to renewable energies, and, among fossil fuels, a shift from coal and oil to natural gas (Lewis 2013). The role of natural gas in China's primary fuel mix has always been small. The share of natural gas was almost zero in 1953 and it has taken almost 60 years to rise to five percent in 2012 (Figure 1.2), approximately the level of Africa on average (Evans & Farina 2013, p.17). Specifically, the FYP seeks to raise the share of natural gas increase to 10 percent by 2020 with a view to reducing the country's dependence on coal and the coal-induced air pollution and carbon emissions, and it is expected that the country's gas demand will continue to grow in the decades to come. A General Electric report estimates that China is the only region in the world that will see a double-digit growth rate year-on-year in terms of absolute gas consumption during 2012-2025 (Evans & Farina 2013, p.20). To put into perspective, China's gas demand is now slightly less than the combined size of German and British gas markets (BP 2013), but it will grow to match the market size of the entire European Union, or of Russia, by 2035 (International Energy Agency 2013).

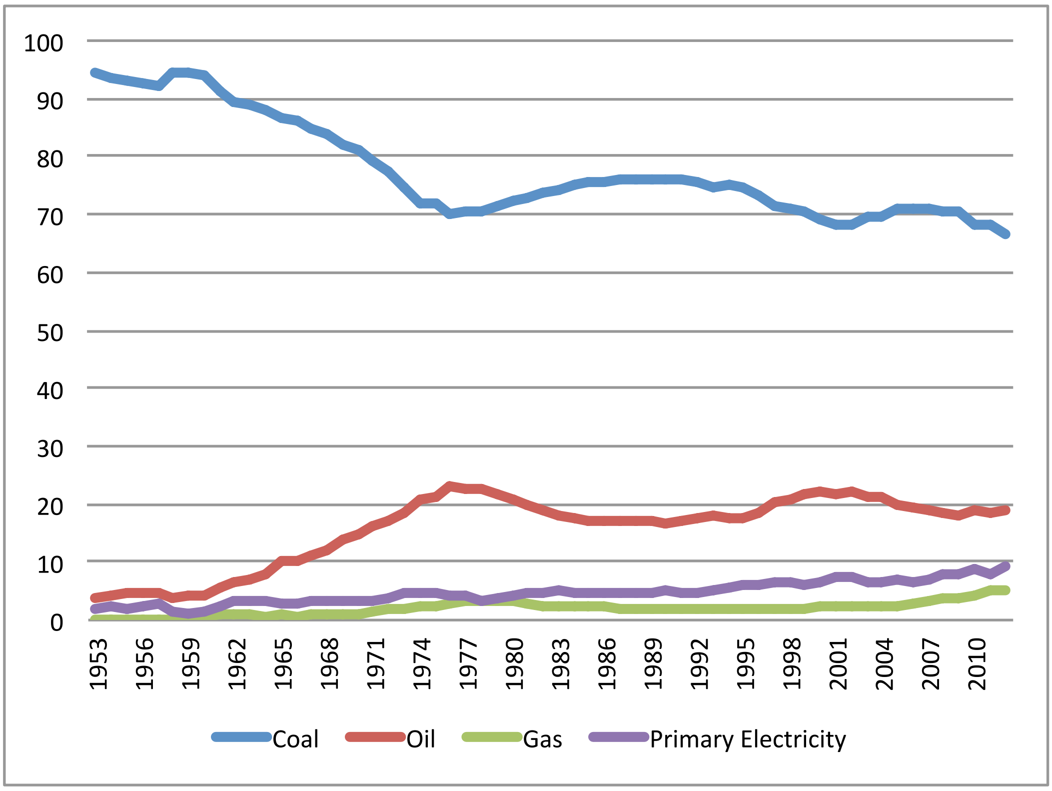
Figure 1.1 China's Primary Energy Consumption, 1953-2012 (Mtce)



Note: Mtce = million tonnes of coal equivalent

Source: CEIC (2014)

Figure 1.2 Transitions in China's Primary Energy Consumption Structure, 1953-2012 (in percentage)

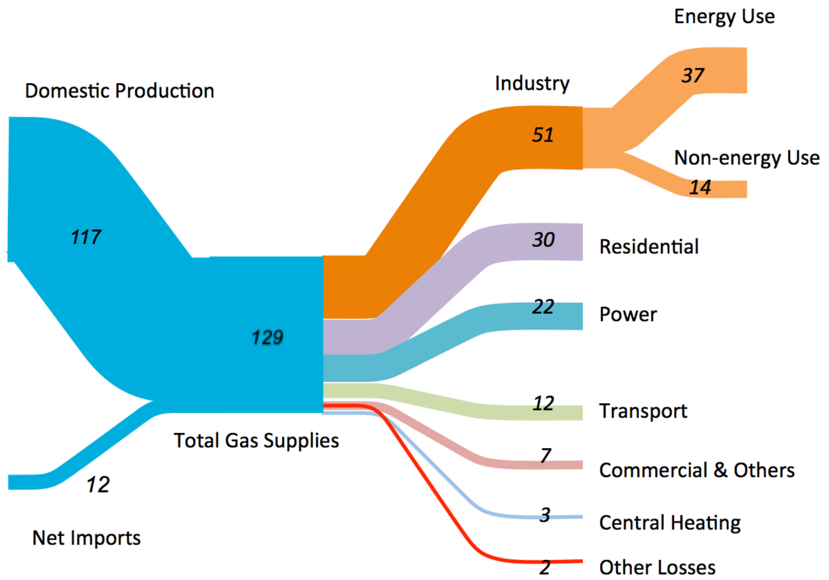


Source: CEIC (2014)

1.2. Aims and Objectives

Such a natural gas transition can be understood as a transition in social-technical regimes that extends way beyond a mere statistical adjustment of China's fuel mix. This study seeks to show how diverse social interests associated with natural gas are effectively coordinating and shaping a low carbon transition in the Chinese energy system. It introduces the Global Production Networks (GPN) approach (which will be thoroughly discussed in Chapter 2) in order to focus on the organisation and coordination of natural gas as a political-economic activity and understand how this social-technical transition unfolds. China's official quest for gasification - i.e. to raise the share of natural gas in the national fuel mix - requires, and will result from, gasification of the country's energy supply-chain systems. It therefore implies transitions in a number of infrastructures, actors and institutions in and across space. Specifically, it implies (i) an increase in the commodificaion of raw natural gas, (ii) expansion and upgrade of infrastructure for gas imports, distribution and storage, (iii) marketisation and regulation, as well as (iv) necessary changes in spatial embeddedness, such as place-based consumption cultures and gas use technologies. Figure 1.3 offers an overview of China's gas flows and shows that China's natural gas supplies come from both domestic and international sources, implying that the increased gas consumption demands increased exploration and development by domestic producers, and deepened interconnections with foreign suppliers. To promote gas demand also invites questions about how to increase gas use in non-traditional gas-consuming sectors in China, such as power generation and transport. For example, gas provided only 2 percent of China's power generation fuel inputs in 2012, which was extremely low by international standards (Farina & Wang 2013, p.11).

Figure 1.3 China's Natural Gas Flows, 2011 (Bcm)



Note: There is an officially unexplained "statistical difference" between the sum of gas supplies (129 Bcm) and the sum of consumption and loses (127 Bcm), due to statistical rounding, conversion and system errors.
Source: Data from CEIC (2014)

Specifically, this study is interested in understanding how a range of gas firms and state actors are connected functionally, organisationally, institutionally and politically, in and across space, to realise the officially proposed natural gas transition in China. The study seeks to uncover the forms, opportunities and challenges of the gasification process. It also aims to serve as an intellectual response to the GPN approach. In short, the study's objectives can be summarised as follows:

- First, it evaluates the functional integration of gas extraction, commodification, trade, distribution and consumption embedded in China's gas transition, so as to conceptualise how different parts of the gas supply chain are dialectically shaped by one another. Rejecting the traditional one-way, linear imagination of a supply chain, a GPN approach highlights the mutual constituitiveness of different functional components embedded in the chain.

- Second, it unpacks the organisational networks between the state and firms, among firms, and within individual firms, differentiating their interests, roles and power, and making sense of the governance structure. For example, a national oil company (NOC), a domestic gas distributor and an international oil company (IOC) formulate their value- capturing strategies differently because of their various ownership structures, levels of vertical integration, geographical presence and access to the resources and markets.

- Third, it analyses the institutional context of China's gas production networks by examining the roles of different state actors and institutions at a variety of scales. Given the significance of state capital and regulation in China's political economy, it is crucial to understand how the complicated political and administrative relationships among the Chinese Communist Party (CCP), Chinese government and NOC take shape around the gas industry, and how these relationships affect firms' access to resource, geological knowledge, market and officials with political influence.

- Fourth, it assesses the non-institutionalised and uncodified political practices around gas in China, (primarily through interviews), so as to gauge how the gas politics of China works and unfolds. These non-institutionalised practices, for example, include departmental bargaining within the central government, or the opaque process of gas distribution licensing at the local level.

- Fifth, it captures the complex spatiality of the gas industry, particularly the sub-national variation, central-local relations, and spaces of flow.

- Sixth, through above analyses, it sheds light on the patterns in which the gas transition unfolds, its sources of uncertainty (e.g. future role of gas in power generation), and its institutional and supply chain challenges, such as the conditionality of strategic coupling, regulated gas pricing and rent-seeking activities of NOCs.

- Finally, it unearths the implications of the organisational and spatial characteristics of the gas production network in China for the theorisation of GPN approach.

Given the complexity of the natural gas landscape in China, and my limited access to relevant data, literature and informants, this study is by no means exhaustively comprehensive. The case studies adopted in the dissertation are indeed selective and partial, but I believe that they can still provide windows on the very complicated and dynamic landscape of China's gas GPN, through which a set of internally consistent observations and arguments may be presented. Based on fieldwork and an extensive literature review, this research is believed to be the first in-depth GPN/supply-chain study of China's gas industry in both Anglophone and Chinese literatures.

1.3. Thesis Structure

This dissertation consists of seven chapters.

Chapter 2, in its first part, reviews the literatures on energy geography and GPN to shed light on the problematisation, conceptualisation and operation of the research on China's natural gas transition. The second part of Chapter 2 presents the research perspective of this dissertation, explains the secondary data sources, and outlines the research design.

Chapter 3 investigates the relational landscape of China's gas GPN from the perspective of the state and its actors and institutions. It argues that studies on any industries in China should begin by specifying the institutional and supply chain role of the state actors to these industries or sectors, because the underlying structures taking shape around them are dominated by the governments and state-owned enterprises (SOEs). This relational landscape has fundamentally determined private firms' access to resource (upstream), logistics (mid-stream) and market (downstream).

Chapter 4 looks at the actors and institutions involved in the acquisition of gas sources in China in the forms of domestic production and gas imports. It confirms the GPN perspective that the extraction sector, unlike manufacturing and services, is shaped not only by social production but also by natural production. Besides, it examines the development of pipeline gas and liquefied natural gas (LNG) imports and points out the geopolitical factors involved.

Chapter 5 outlines the trends in the development of China's gas-moving infrastructure, which has been volumetrically increased, geographically expanded and organisationally diversified. The detailed case study of the West-East Gas Pipeline has offered a partial window through which we understand that China's fragmented energy decision-making, discussed in Chapter 3, is ironically capable of fast-tracking large-scale regional transmission gas pipelines. It has also highlighted the institutional and infrastructure challenges of gas distribution, and how the discontinued networks of inland LNG/compressed natural gas (CNG) logistics supplement the regional transmission pipelines. At the city-level, it has also revealed why the NOCs have looked for a higher degree of vertical integration by setting foots in the downstream gas industry, an unnerving trend to independent players.

Chapter 6 analyses the pattern of, and factors involved in, geographical and sectoral gas consumption in China. It, in turn, investigates the role of gas in power generation, industry, transport and building (residential and commercial), and the actors and institutions associated.

Chapter 7 concludes the dissertation by summarising the major empirical findings and arguments, and their theoretical implications for the GPN framework.

Chapter 2 Literature Review and Research Design

2.1. Literature Review

The overall goal of this dissertation is to analyse the gasification of the Chinese energy economy. A critical review of the literature – in energy geography and global production networks (GPN) – is beneficial to the problematisation, conceptualisation and operation of the research in two ways. First, an extensive survey of the existing literature helps identify academic gaps that justify carrying out this study, and sheds light on how it could respond intellectually to the problem of energy transition. Second, an overview of methodologies and approaches in this sub-field helps position the research framework adopted. The following literature review will begin by discussing the boundary of "energy geography" as a sub-field. It will then review a small number of related core concepts, including energy as a factor of production, energy scarcity and energy transition. Although formally outside of this sub-discipline, energy governance and energy security will also be briefly reviewed. The literature review, however, will be mainly focused on GPN, including its theoretical parents, core concepts, building blocks, applications and limitations. Finally, a summary of this section will also be given.

2.1.1. 'Energy Geography': an emergent sub-field?

Is there such as a sub-field of geography called energy geography? The answer to this taxonomical question largely depends on the criteria one adopts for boundary building. There does not seem to be a coherent or uncontested set of philosophies and methodologies adopted by geographers when they deal with energy issues. Indeed, the community that comprises "energy geography" is loosely formed by physical, environmental and human geographers, as well as by non-geographers (political scientists, economists, engineers and sociologists) whose works carries geographical interests. As a result, the boundary of energy geography as a field of study is blurred and dynamic: it contains multiple concepts and methodologies, some of which are contested. Energy geography, in other words, can be defined as a thematic collection of scholastic works that originates not only in Geography but also from further afield (Zimmerer 2011).

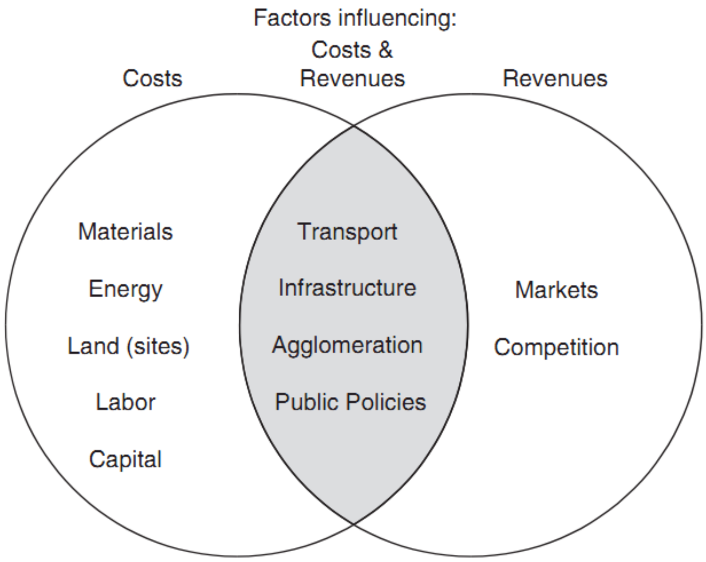
Geography as a discipline has a long-standing "regionalist" tradition of enquiry, in which geographers saw the region as a spatial container and strove to understand its geology, resources, economies and societies. This "idiographic" tradition focused on describing features of particular regions in an encyclopedic way, rather than aiming for systematic forms of enquiry and theory building. A great number of recent geographical works on energy are still in line with this tradition. Contemporary works such as Thomson & Horii (2009), Thomson (2011), Leung et al. (2011) and O'Hara & Lai (2011) focused on the energy geography of China, are illustrative of a strong tradition of descriptive regional analysis. Their works relied heavily on data mining and mapping that shows the uneven distribution of energy resources and infrastructure, with some emphasis on the history of the region. They treated the region as a spatial container that holds some "objective", "technical" information. Similarly, Moe & Kryukov (2010) review trends in exploration of oil, recent developments in its financing, reorganisation of exploration activity and the evolution of Russia's licensing system. Bradshaw (2010a) presents a comprehensive technical account of the development of the onshore and offshore oil and gas deposits of Sakhalin. When Dadwal (2009) analysed the energy security issues of India, he did so around facts, figures and maps—GDP, energy reserves, locations, details of ongoing and planned projects, fuel mix, balance of trade, etc.—without a comprehensive account of the concept of energy security. Older literature in this line of research includes, for example, Farrell (1962), Hooson (1965), Dienes & Shabad (1979), Hart (1980), Hoffman (1985) and Croissant & Aras (1999). Describing this research approach as 'traditional' does not mean that it is unimportant or antiquated. Studies of energy transition, even those with a critical and theoretical aim, need to be backed up with empirical understanding and regional detail, or they risk over-theorisation or hasty extrapolation. Michael Bradshaw, for example, follows this tradition when he approaches energy issues in some of his studies but aims to theorise or systematise the regional characteristics in his other studies. Bradshaw's work on the Russian oil and gas industry illustrates this point: it is well-grounded in the empirical context while his works on global energy dilemmas aim at building a coherent theory or framework that attempts to bind together energy security problems, low-carbon transition and economic globalisation (Bradshaw 2010b, 2013).

It is within the sub-disciplines of economic, political and development geography, and in work on climate change and on urbanisation, that geography has begun to engage most with issues of energy. However, within each of these specialisms, energy does not play a large role. This is perhaps most striking in the contemporary study of economic geography, notwithstanding the importance of energy to the operation of the economic system and production networks. Because work on energy in geography does not fall along traditional sub-disciplinary lines, this review focuses on a small number of core concepts: energy as a factor of production; energy scarcity; energy transition; energy governance and energy security.

A. Energy as a Factor of Production

Up until recently, energy has been considered largely as an industrial or production cost, especially within location theory and "industrial geography" more generally. Location theorists hold that different manufacturing processes demand different sets of inputs; an iron and steel manufacturing factory, for example, is more energy-intensive than others. A substantial literature has examined the interplay between spatial variations in the availability and cost of the multiple inputs, including energy, required by industrial processes, the geography of demand for the outputs of these activities, and the choice of location for new factories. Chapman (2009) points out that, although typologies of "locational factors" draw upon a wide range of empirical surveys, the logics of location theory may be simplified: Figure 2.1 distinguishes between those factors primarily influencing the cost of production, and those primarily influencing revenues earned by selling manufactured goods. In this sense, energy is considered no more than a raw material or, in classical economic term, a factor of production, and its cost is responsible for shaping the spatial pattern of industrial locations. Starting from Weber's premise that the best location is the one at which costs are minimised, Sakashita (1980) and Hwang & Mai (1987), for example, evaluated the topological impacts of rising energy prices on the patterns of industrial location in the 1980s.

Figure 2.1 A Typology of Industrial Location Factors



Source: Chapman (2009, p.397)

On the other hand, several strands of research with very different approaches and perspectives underscore the wider social relations embedded in energy commoditisation, circulation or consumption. Working from a neo-Marxian perspective, some economic geographers approach energy as a commodity: geographies of energy, from this perspective, reflect the dialectical interplay between exchange value (market circulation) and use value (consumption). Although Debeir et al. (1991, p.xiii) state that energy is one of the "main blind spots in Marxist thought", a number of economic geographers have sought to address the relations between fossil fuel and capital accumulation in industrial capitalist societies. Huber (2009), for example, proposes a dialectical conception of energy as embedded in dynamic social processes and power relations, noting how ecological economics was perhaps the only sub-discipline to attempt a serious theoretical integration of energy into economic analysis. Martinez-Alier (1987), for example, has traced the long history through which economists, natural scientists and philosophers have called for the application of thermodynamic principles to the analysis of economic systems. Huber's work, however, held that ecological economics treats energy as the kind of "transhistorical" abstraction that applies to all human societies at all levels of interaction with the natural environment, so that ecological economics risks making the mistake of "energetic determinism" (p.106). He went on to argue that fossil fuels are an historically specific mode of energy, and we should move from conceptions that understand energy as a thing or a resource towards a conception of energy as a social relation embedded in "dense networks of power and sociological change" (Huber 2009, p.106).

The group of economic geographers or scholars interested in conceptualising commodity chains and networks also tend to put energy into a wider perspective of social relations and regard these relations as something embedded in complex networks of institutions and territorialities. In contrast to a view that takes energy merely as a production input, these scholars look at each stage of the commodity chain—from production to transformation (commoditisation) to distribution to consumption: some go even further to also take account of the institutional and territorial embeddedness of each of these steps. For example, Ciccantell & Smith (2009) found that the Global Commodity Chains of oil has to be understood through the consideration of its institutional and territorial contexts; otherwise, researchers, they argued, would not be able to explain why Iraq's oil sector has received much less foreign investment than Alberta's oil sands sector. Odell made a similar argument; he insisted that the geographical location of oil production is not solely affected by transport costs, but is "tempered by forces of a non-economic character" (Odell 1997, p.312), such as protectionism, security of markets and of supply and issues of geopolitics.

B. Energy Scarcity

A number of researches contribute to understanding the social-economic dimension of energy scarcity. For human geographers, energy scarcity is not a physically determined concept but it is socially constituted. The availability of energy resources is not static but is a function of prices, knowledge, investment, demand and power relations —as Zimmerman (1951) famously suggested: resources are not; they become. In his *Consuming Power*, Nye (1998) reviewed the social history of America as seen through the lens of energy consumption. He showed that the crux of the situation that the US became the world's largest energy consumer is less a question about the development of technology than it is a question about the development of culture. He looked at how the energy consuming activities changed as new energy systems were constructed from colonial times to recent years. He showed how, as Americans incorporated new machines and processes into their lives, they became ensnared in energy systems that could not easily changed. While people made choices about the conduct of their lives, and those choices accumulated to produce a consuming culture—in other words, once the system of high energy consumption is formed (e.g. existing road networks, car stock, energy-inefficient buildings), new status quo is locked in, and a consuming culture is created and reinforced, echoing the path-dependent view of energy systems.

C. Energy Transition

A group of scholars, therefore, aim to deconstruct the process of "energy transition”. The coverage of energy transition works in the 1970s centred on fuel substitution and resource limitation (Araújo 2014). For example, the concept "energy ladder" has become used to describe the transition of households (mainly in the developing world) from utilising traditional energy carriers for their energy service needs to utilising more modern, technologically sophisticated energy carriers to meet those needs. It draws an analogy between household fuel choice and a ladder. Households using traditional fuels—such as firewood or dung—are assumed to be on the lower rungs of the ladder. Households using modern, commercial fuels—such as LPG, natural gas, or electricity—are assumed to be poised on the upper rungs of that ladder. Although this transition is of most concern to households in developing countries, a similar process is assumed to have taken place in developed countries as they went through the process of industrialisation (Hosier 2004). In its World Energy Outlook 2002, International Energy Agency (2002) adopted this concept for analysing the energy poverty issues in the developing world and presented its characterisation of energy ladder.

Hosier (2004) identified the factors (drivers and constraints) that affect the household energy transition, namely household income, urbanisation, smoke emissions and exposure, appliance costs, relative fuel costs and prices and fuel availability. The framework of "energy ladder"—developed from a general understanding of household budgetary decisions, a knowledge of the development process, and a familiarity with the differences in energy use patterns between more developed and less developed countries—serves as a loose conceptual framework, but is not without problems (Hosier 2004). First, it assumes that most if not all households will move progressively from traditional fuels to more modern fuels in a predetermined succession, failing to account for the complexities of actual household fuel usage and energy decision-making. Second, the concept is too "modernist": it regards the modernity of society and the fuels associated with a society at a particular “stage” of development. Third, the energy ladder studies have been built mostly on household energy surveys providing a snapshot of energy consumption at a particular point in time; in other words, they are built on differences between households at one point in time rather than on longitudinal evidence documenting changes in time among the same households. Fourth, it does not consider the power relation and gender issues within each household unit. For example, in rural households, it may not be unusual that women are charged with collecting firewood and cooking, while men control financial resources. For the sake of convenience and reducing exposure to toxic smoke, women might want to move up the energy ladder, but are prevented from doing so by an unwilling husband who controls the household's financial resources. Finally, the ability of the energy ladder to yield predictive insights into the household energy transition is more consistent in urban areas than rural areas (Hosier 2004).

The contemporary understanding of energy transition moves beyond the energy ladder framework. According to Smil (2010), although there is no formal or generally accepted hierarchy of meanings of this concept "energy transition", it is used most often to describe the change in the composition (structure) of primary energy, the gradual shift from a specific pattern of energy provision to a new state of an energy system. But recent works on energy transitions also focuses on how development in technology, information and practices can alter the way that energy is used by recognising the change related to fuel type, access, sourcing, delivery, reliability and end use (Araújo 2014). This transition can be traced on scales ranging from local to global, and is relevant for societal practices and preferences, infrastructure, as well as oversight. A dominant perspective for thinking about energy transition in the social sciences is the multi-level perspective, for which the work of Geels (2010) provided an anchor point. Geels proposes three analytical levels of transition: niches (the locus for radical innovations), socio-technical regimes, which are locked in and stabilised on several dimensions, and an exogenous socio-technical landscape. They and their interactions bring about a multi-level perspective (MLP), which allows researchers to examine the role of experiments and niches in relation to the existing socio-technical regimes (Hodson & Marvin 2012). For example, the work of Hodson & Marvin (2012, p.422) contributes to the understanding of the role of cities, “key sites of consumption in complex socio-technical networks”, withhin national-level low-carbon energy transitions.

D. Energy Governance and Energy Security

Human geography has a long standing interest in energy production/conversion as a "social problem" that requires some form of rational management, such as power station siting, or other "locally-unwanted land uses" (LULUs). For example, following the nuclear disasters at Three Mile Island in 1979 and at Chernobyl in 1986, energy geographers carried out a number of significant studies to understand risk perceptions and behavioural responses (Pasqualetti & Pijawka 1984, Blowers et al. 1991), safe power plant siting (Openshaw 1986, ORiordan et al. 1988), decommissioning and its social costs (Pasqualetti 1990, Pasqualetti & Pijawka 1996), the transportation and disposal of nuclear waste

(Openshaw et al. 1989, Jacob 1990), lessons about democratic principles that one could draw from the Soviet Union's 1986 Chernobyl explosion (Gould 1990), the degree to which nuclear power had spread around the world by the early 1990s (Mounfield 1991), and the issues of nuclear site remediation (Greenberg et al. 1998). In the past few years a group of global governance scholars have begun to develop a significant literature on broad frameworks for understanding energy governance beyond the national level (Cherp et al. 2011, Colgan 2010, Florini & Sovacool 2009, Goldthau & Witte 2009, Keohane & Victor 2011, Pascual & Elkind 2010). The literature on global energy governance, though most of which are formally outside of geography, generally emphasises the importance of actors, institutions, network and embeddedness (Andrews-Speed 2012), which is echoed by the GPN approach, discussed below.

Similarly, recent literature on energy security has also moved beyond the traditional state-level analysis and called for richer and more comprehensive accounts. The tradition understanding of energy security—state-centric, supply-based, oil-biased—has been strongly influenced by the perspective of inter-state great powers geopolitics. It has been tied to the supply of fuels for the military after the British Navy and others switched from domestic coal to imported oil in the early 20th century (Bradshaw 2009). The official interpretation of China's energy security is similarly focused on the country's climbing energy imports and the associated geopolitical vulnerability. Most scholars implicitly equate China's energy security with the security of its oil imports (Downs 2004, Zha 2006, Zhang 2011). However, already in 2003, Chen Xinhua (cited in Kennedy (2010, p.143)), a former programme manager for China at the International Energy Agency, was dissatisfied with this focus and stated clearly that "energy security must first be dealt with domestically". More recently, scholars have highlighted that domestic energy issues are relevant to China's energy security (Kong 2011).

Drawing data from over 300 Chinese and over 100 English publications and 30 interviews with energy officials and experts in China, this author and his colleagues (Leung et al. 2014) argue that China's focus on securing its oil supplies at the expense of improving the reliability of domestic electricity generation has its roots in historic events, objective properties of vital energy systems, as well as the presence of powerful institutional agents capable of securitising oil but not of other vital energy systems. We suggest that this focus on oil imports is likely to be maintained in the future, but it will be accompanied by increasing concerns over natural gas (and electricity) and over domestic robustness and resilience of energy supply chains.

2.1.2. Global Production Networks (GPN)

The development of a Global Production Network (GPN) approach has contributed a great deal to the broader "relational" turn in economic geography (Bathelt 2006, 2009, Bathelt & Glückler 2003, 2005, Yeung 2005). Economic geography has traditionally either not focused on the firm or where it has, see firms as discrete actors (Swyngedouw 1997). It has also over-depended on physical spatial proximity to explain location decisions and spatial distributions of economic activities (Sheppard 2000). Accordingly the last two decades have seen calls for an "institutional turn" (Amin 1999, 2001), a "cultural turn" (Crang 1997) or a "relational turn" in economic geography.

Relational frameworks are diverse, however, and it may be said that there are divergent and polysemic meanings of "relational". To some, relationality is linked to Marxist dialectics—for example, capital cannot be understood independently as a thing but a social process; key elements of society, such as the proletariat, cannot be meaningfully analysed independent of their relation to other elements, such as the bourgeoisie. For others, such as those working with GPN/global commodity chain (GCC) approaches, "relational" means assemblage into networks, and places an emphasis on understanding interactions and the process through which "wholes" (for example, production chains) are constructed. For example, Bathelt & Glückler (2003) interpret the relational approach as a way of seeing that tries not to isolate those aspects of human life which are inseparable and to consciously integrate economic and social, cultural, institutional and political aspects of human agency. Yeung (2005) regarded relational economic geographers as the group of scholars who place their analytical focus on the complex nexus of relations among actors and structures that causes dynamic changes in the spatial organisation of economic activities.

Since the pioneering GPN work of Henderson et al. (2002), the GPN literature has seen much development and invited many debates and critiques. As a perspective rather than a theory, GPN is "a heuristic framework for understanding the interconnectedness and uneven development of the global economy" (Coe 2012, p.1). The GPN approach captures how "the reshaping of the global economic map has been driven increasingly by the emergence of extremely complex organisational and geographical networks of production, distribution and consumption" (Dicken 2011, pp.429-430). In terms of epistemology, GPN scholars seek to uncover the multi-actor and multi-scalar characteristics of transnational production systems, the mutual transformation of firm and place, and their developmental implications through employing the intersecting notions of power, value, and embeddedness (Coe 2009). It is fair to say that the current GPN literature reflects essentially the Manchester School's representation of the real-world production networks (Bathelt & Glückler 2005, Yeung 2005): this means that there could be, in principle, other theoretical variants.

A. The Making of GPN: Intellectual Antecedents

We can broadly identify five intellectual antecedents of GPN (Henderson et al. 2002, Hess & Yeung 2006, Coe et al. 2008, Coe 2009, 2012). The first one is the value chain framework for strategic management developed in the early 1980s. Through the work of Michael Porter (Porter 1980), the concept of "value chains" gained pre-eminence in a range of research, but it did not find its way into economic geography until the work of Dicken (1986). The value chain framework, in retrospect, has inspired GPN theorisation, particularly the explicit concern with how value is created, enhanced and captured, and in the recognition of the inseparability of manufacturing and service activities in economic production (value-added processes).

Second, GPN studies owe most to the analytical frameworks of global commodity chains (GCCs) and global value chains (GVCs). Emerging from the development studies tradition and Hopkins and Wallerstein's world-systems theory (Hopkins & Wallerstein 1982), GCC/GVC analysis gained prominence after the mid-1990s, following works by Gereffi in particular. Gereffi (1999) differentiates his concept of GCC from Porter's concept of "value chains", in part by stating that GCC analysis embodies an explicit transnational dimension. The GCC framework not only highlights the importance of coordination across firm boundaries, but also the growing importance of new global buyers (mainly retailers and brand marketers) as key drivers in the formation of globally dispersed and organizationally fragmented production and distribution networks. According to Gereffi (1994), GCCs come in two major categories: Producer-driven global commodity chains tend to have high barriers of entry as commodity chains require capital/technology intensive production and economies of scale, such as in the automobile and aeronautical industries, whereas buyer-driven global commodity chains tend to have low barriers to entry. Producers are bound to the decisions of buyers through the functions of design and marketing, notably where retailing and brand names are concerned. In terms of GCC research, the most significant sectors have been agriculture, garments, footwear and toys.

While GCC researchers have produced an impressive body of work, the GCC framework and literature have seen six apparent limitations and difficulties. To begin with, although world-systems theory aims for a comprehensive analysis, the GCC literature, in practice, has not explored the whole input–output structure. The literature is largely focused on the production side and neglects extraction, transportation, final consumption or other stages on the chains. Second, when it comes to territoriality, GCC literature is overly state-biased, focusing on the national scale with less attention paid to the complex processes of sub-national development. Third, related to the second point, although GCC pays some attention to territoriality it tends to downplay the factors of institutional and territorial embeddedness. Some GCC researchers have realised this problem recently. For example, Ciccantell and Smith (2009) explain although Iraq's crude oil is of higher quality (favourable materiality) and sits on the geographical centre of the world oil market (favourable location), Iraq's oil sector has received much less foreign investment than Alberta's oil sands sector (poor quality and less favourable location). This cannot be explained without taking institutional (e.g. UN sanction) and territorial embeddedness (e.g. history of conflicts and violent geopolitics) into account. Simply put, the ignorance of institutional and territorial embeddedness naturally overlooks differential barriers to entry into the various product markets (Dicken 2011).

Fourth, while the GCC framework has identified four analytical dimensions (input–output structure, territoriality, governance regime, and an institutional framework), the discussion of governance structures has dominated the literature, and the distinction between producer and buyer driven chains is often too crude to incorporate the complexity of the power relations (Coe, 2009). Fifth, as Gereffi (1994) explained, GCC refers to the sequential stages of input acquisition, manufacturing, distribution, marketing and consumption. But as Henderson at al. (2002, p.442) put it: “a major weakness of the ‘chain’ approach is its conceptualisation of production and distribution processes as being essentially vertical and linear”. Indeed, the whole “chain” metaphor tends to produce certain misleading geographical imaginaries in which material and non-material flows of production are determining, one-way and linear. In fact, even if we turn a blind eye to all the complex institutional and territorial embeddedness and networks of actors for a moment, and look only at the sequential stages of input-output, the chain metaphor is still invalid: while the material flow runs one direction, the non-material flow (e.g. information and reinvestment) runs in the other. For this reason the notion of a circuit – rather than a chain – has been proposed as a better metaphor (Dicken 2011).

Finally, GCC theorists have yet to fully realise the importance of intra-firm relationships. One dimension of globalisation is the deep integration of economic actors, and a dimension of this deep integration is the widespread intra-firm trading of transnational corporations (TNCs). TNCs currently account for around two-thirds of world exports of goods and services, of which a significant share is intra-firm trade, the kind of trade that is across national boundaries but is within the boundaries of the firm. Intra-firm trade accounts for at least one-third of total world trade (Dicken 2011, p.20).

More recently, the notion of the GCC has been partly superseded by the work that conceptualises Global Value Chains (Coe 2009). As mentioned, GCC's binary of producer/buyer governance is a bit too raw to capture the real-world situation: In fact even Gereffi et al. felt that this binary distinction was somewhat crude, stating "the global commodity chains framework did not adequately specify the variety of network forms that more recent field research has uncovered" (Gereffi et al. 2005, p.82). For example, work on the electronics industry and contract manufacturing by Sturgeon (2002) contrast three types of supply relationships, based on the degree of standardisation of product and process: (i) the "commodity supplier" that provides standard products through arm's length market relationships; (ii) the "captive supplier" that makes non-standard products using machinery dedicated to the buyer's needs; and (iii) the "turn-key supplier" that produces customised products for buyers and uses flexible machinery to pool capacity for different customers. Therefore, Gereffi et al. (2005) proposed a more complex typology of value-chain governance. They first identify key determinants of value chain governance patterns: (i) the complexity of transactions (the complexity of information and knowledge transfer required to sustain a particular transaction, particularly with respect to product and process specifications); (ii) the codifiability of information (the extent to which this information and knowledge can be codified and, therefore, transmitted efficiently and without transaction-specific investment between the parties to the transaction); and (iii) the capability of suppliers (the capabilities of actual and potential suppliers in relation to the requirements of the transaction). Then they find that if these three factors are allowed with only two values (either high or low), then there are six possible combinations, of which five are actually found. These five global value chain governance types are (i) markets, (ii) modular value chains, (iii) relational value chains, (iv) captive value chains and (v) hierarchy. Through looking at supplier capabilities and different forms of knowledge within value chains, GVC approaches have developed a more sophisticated typology of governance regimes, with captive, modular, and relational forms being identified alongside traditional market and hierarchy forms. The identification of these five forms of governance structure has influenced certain GPN studies, such as Murphy & Schindler (2011).

The network approach of GPN is partly developed from the networks and embeddedness perspectives in economic and organizational sociology since the mid-1980s. Sociologists have been interested in social network analysis since the 1920s and the 1930s (Kilduff & Tsai 2003). But it was not until the mid-1980s that the idea of economic action being embedded in networks of ongoing social relations was resurrected by the work of Granovetter (1985). Since then, this idea of embeddedness and networks has strongly reverberated in management and organisation studies, and later economic sociology, organisation studies and strategic management (Smelser & Swedberg 2005). Its diffusion into economic geography took place in the early 1990s (Peck 2005, Grabher 2006). In particular, Dicken & Thrift (1992) suggested that economic geographers take networks and embeddedness seriously in the geographical analysis of firms and their productive activities (this is where the above-mentioned relational turn in new economic geography emerged).

Despite the introduction of an embeddedness framework that relies on the structural analysis of network relations, the role of geographical agents such as firms is still missing. This is where some economic geographers have turned to actor-network theory (ANT). Emerging from the sociology of scientific knowledge, ANT emphasizes the relationality of both objects and agency within heterogeneous networks, pointing out that entities in networks are shaped by, and can only be understood through, their relations and connectivity to other entities (Law 1999). Another key idea from ANT is the rejection of traditional analytical binaries, such as structure/agency, and recognition that nonhuman forms, especially technologies, are an integral component of networks (Henderson et al. 2002). However the utility of ANT to the study of global economic networks is somewhat constrained (Coe 2009), as it downplays the structural preconditions and power relations that in effect provide the “rules of the game” for the formation and operation of production networks.

Related to Coe's concern regarding ANT's inability to discern the “rules of the game”, GPN tries to overcome this difficultly by incorporating the particularities of what are called “varieties of capitalism” from the study of comparative political economy, which is the study of differences between political-economic systems across national boundaries.

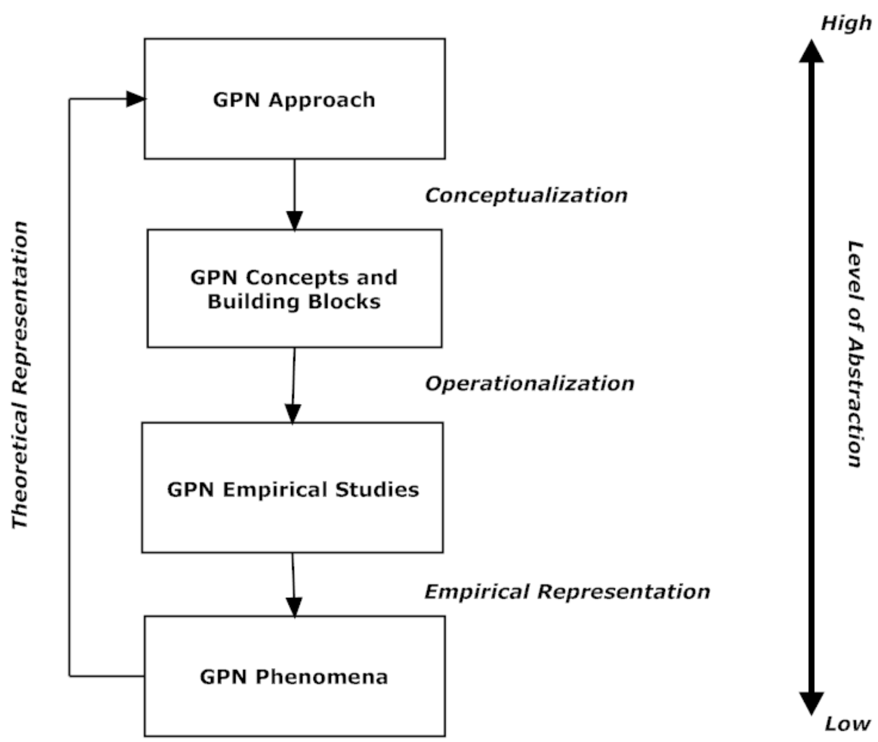
The demise of the Soviet Union marked the end of Cold War, and capitalism emerged to be the single dominant ideology, or way to organise economic activities. A singular world of market unification and institutional convergence seemed to beckon and alternatives became seemingly impossible or unnecessary. But before long this vision of a victorious and unitary capitalism met a critical countercurrent. A heterogeneous group of scholars started revealing resilient national territorial differences in the organisation and trajectories of capitalist systems (Hall & Soskice 2001, Peck & Theodore 2007). Hall & Soskice (2001) identified three strands of thought in the varieties of capitalism literature: (i) a modernisation approach, which sprang out of post World War II rebuilding and focused on the ability of national governments to create growth; (ii) neo-corporatism, which centres on the ability of firms and states to work together to drive national forms of economic growth; (iii) and the social systems of production literature, which focused more heavily on changing structures in production and regional and sectoral institutions. As an approach, varieties of capitalism highlights how competitive capitalism would not get to establish a monopoly at the planetary scale; rather, a re-invigorated process of competition between national capitalisms was taking shape. Albert (1993) vividly characterised this as a struggle of "capitalism against capitalism". Broadly speaking, one can categorise capitalism within different bounded spaces of states into four types, including neo-liberal market capitalism, social-market capitalism, developmental capitalism and authoritarian capitalism (Dicken 2011). Of course, this is a general classification and further varieties exist within each of these four. Besides a general worldview, GPN theory inherits from varieties of capitalism its relational, firm-centred, multi-actor and dynamic approach. As Hall and Soskice (2001) stated clearly:

> The varieties of capitalism approach to the political economy is actor-centred, which is to say we see the political economy as a terrain populated by multiple actors, each of whom seeks to advance his interests in a rational way in strategic interaction with others...The relevant actors may be individuals, firms, producer groups, or governments. However, this is a firm-centred political economy that regards companies as the crucial actors in a capitalist economy. They are the key agents of adjustment in the face of technological change or international competition whose activities aggregate into overall levels of economic performance (Hall & Soskice 2001, p.6).

B. The Value of GPN as a Network Approach

Having reviewed its intellectual antecedents, this section characterises the value of GPN as a network approach while also considering critiques. The GPN approach seeks to represent real-world phenomena – production networks that are organized transversally across space – and can, like many other theoretical approaches, can be understood from a three-order perspective (Figure 2.2). The first-order perspective (called here a GPN approach) refers to an overarching way of framing questions: understood this way, GPN is a heuristic, network-based device for analysing the complex, multi-scalar, continuously dynamic and mutually constituting relationships between intra-, inter- and extra-firm actors, which are institutionally embedded, across time and space, in order to make sense of transnational economic activities in an era of globalisation. The second-order GPN refers to the conceptual building blocks that make up the overarching approach. The third-order GPN refers to empirical cases which apply the GPN concepts and tools (second order) of the approach (first order): these empirical cases operationalise the concepts. If we see the GPN approach as a kind of cuisine, then GPN concepts and building blocks are ingredients and seasonings, and GPN empirical studies are the dishes. This way of differentiation is, of course, far from perfect, as the boundary can be at times blurred. For example, on the second-order level, if certain concepts are underdeveloped in the GPN theory, such as labour geographies, this implies that relevant studies are also under-explored on the third-order level. Nonetheless, such differentiation enables GPN proponents to better respond to criticisms against GPN at different levels of abstraction.

Figure 2.2 A Three-order Schematic Representation of the Relation between GPN Approach, Concepts, Studies and Phenomena



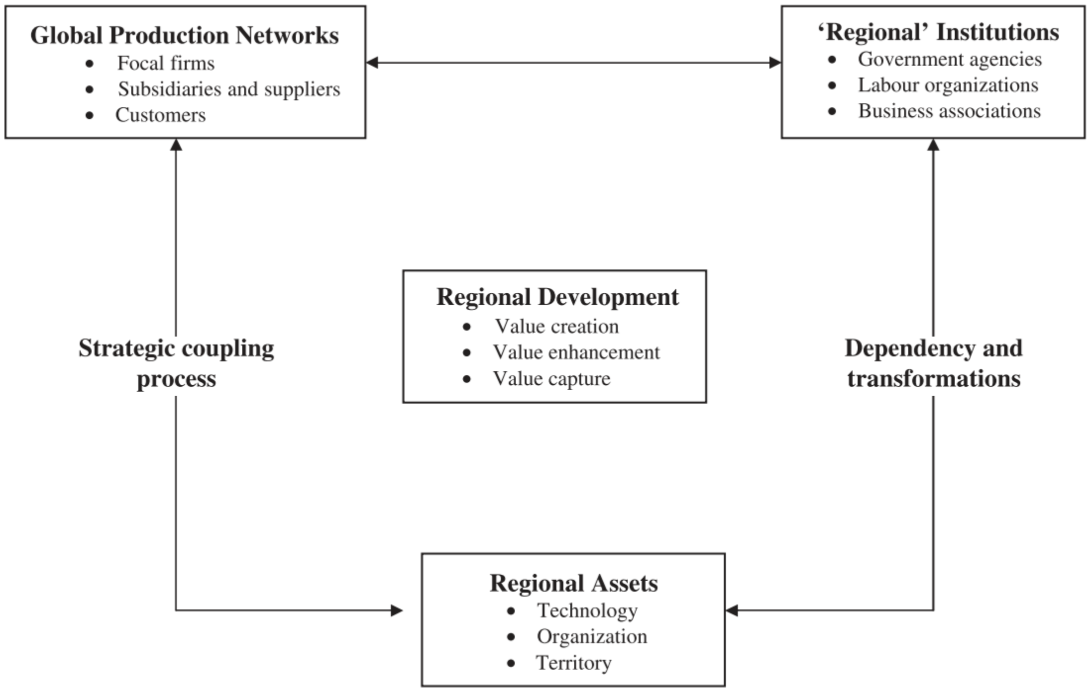
Source: The Author

Distinctiveness of GPN as an Approach

Derudder & Witlox (2010) held that GPN is within the broad GCC paradigm but uses different terminologies. This judgement is partly true on the practical level (i.e. the third-order GPN level) as some argue that the actual presentation and analysis of GPN empirical studies are not much different from those of GCC. But on the first-order level, GPN as an approach is distinctive in five ways (Hess & Yeung 2006, Coe, Dicken & Hess 2008b, Coe 2009). First, although the chain concept in the GCC theory touches on multiple geographical scales, particularly the global scale, GCC theory remains largely a framework from sociology and its geographical angle is weakly developed (Hess and Yeung, 2006). While the GCC framework sees territoriality as highly aggregated spatial units of either core or periphery, Coe (2012, p.2) points out "GPN analysis is innately multi-scalar, and considers the interactions and mutual constitution of all spatial scales from the local to the global". For example, Coe et al. (2004) have made an explicit analytical link between GPNs and sub-national development, a core issue for economic geographers since the 1980s. Second, as Coe, Dicken & Hess (2008a, p.272) rightly observed "production networks are inherently dynamic; they are always, by definition, in a process of flux—in the process of becoming—both organisationally and geographically": as a consequence the governance characteristics of GPNs are taken to be much more complex, contingent, and variable over time than is suggested in GCC/GVC analysis. Third, while GCC analysis, as Taylor (2007, p.534) argued, succumbs to a "network essentialism", ignoring the wider social and institutional context that shapes production, GPN encompasses a broad range of non-firm organisations through the explicit consideration of extra-firm networks. This is also why GPN focuses on "production" instead of "commodity": "the term 'commodity' generally connotes standardised products and with that, the fixity of their production in time and space" while the "preference for a discourse of 'production' places the analytic emphasis on the social processes involved in producing goods and services and reproducing knowledge, capital and labour power" (Henderson et al. 2002, p.444). Fourth, this is explicitly a network approach that seeks to move beyond the analytical limitations of the notion of a "chain", avoiding deterministic linear interpretations of how production systems operate and generate value (Henderson et al. 2002, Hess & Yeung 2006, Coe 2009, 2012). Finally, a central concern of GPN analysis is not to consider networks in an abstracted manner for their own sake, but to reveal the dynamic developmental impacts that result for both the firms and territories that they interconnect (Coe 2009).

The distinctiveness of the GPN framework can be illustrated by its approach to conceptualise the relationship between globalisation and regional development. According to Coe et al. (2004) and Yeung (2009), early formulations of the "new regionalism" and GCCs/GVCs literature failed to effectively grasp the complicated trans-scalar relation between globalisation dynamics and regional development. Whereas the new regionalists were overly pre-occupied with local transactions and institutional forms without realising the many extra-local connections within which regions are embedded, the GCCs/GVCs approaches operated largely at the national scale without paying enough attention to how particular sub-national spaces and their institutions are integrated into, and shaped by, global production systems. The GPN approach derives insights from both literatures, but attempts to offer a new framework that can overcome their difficulties. GPN scholars invented an interface to capture the dynamic relationship between firms and regional assets within production networks. This interface is referred to as "strategic coupling" and is mediated by a range of institutional activities across different geographical and organisational scales (Figure 2.3). Their definition of region is also quite different; they extend further the relational view of regional development and do not conceptualise a region as a tightly bounded space but as a porous territorial formation whose notional borders are cut through by a broad range of network connections (Coe et al. 2004, Yeung 2009). Through the interface of "strategic coupling", they attempt to explore how the interactive complementarities of GPNs and regional assets may (or may not) facilitate regional development, which depends on the processes of the creation, enhancement and capture of value (economic rent) within the region. In this sense, they defined regional development as "a dynamic outcome of the complex interaction between territorialised relational networks and global production networks within the context of changing regional governance structures" (Coe et al. 2004, p.469) and held that it is a highly contingent process that cannot be predicted *a priori*. While broadly consistent with the "new regionalism" and GCCs/GVCs literatures, the GPN approach differs by not confining the coverage of "regional institutions" to those that are regionally specific: instead it expands it to "the supra-national, national and regional institutions that will impact on activities within a region". Yeung (2009) later called it "the trans-regional processes", which is a combination of intra-, inter-, and extra-regional mechanisms that are shaping regional development trajectories.

Figure 2.3 Strategic Coupling and Regional Development



Source: Coe et al. (2004, p.470)

According to Coe et al. (2004), there are three necessary conditions for strategic coupling (and in turn regional development) to take place, namely the existence of economies of scale and scope within specific regions, the possibility of localization economies within global production networks, and the appropriate configurations of "regional" institutions to "hold down" global production networks and unleash regional potential. This implies that having regional assets that complement the strategic needs of focal (lead) firms within GPNs is sufficient to enable strategic coupling, but there is also a need for appropriate institutional networks. Yeung (2009) found that regional developments are highly variegated in the East Asia region because of its differentiated geographical, historical and institutional contexts, ranging from Japan's active pursuit of regional equality policies during post-war development to the strong focus in South Korea and Taiwan on building up national institutional capacity between the 1970s and the 1990s and the more recent experimentation of China with regional devolution since the late 1980s. In later work, Yeung (2012) notes that the strategic coupling of local actors with focal firms in GPNs should not be conceptualized in a functional manner, as this coupling process is not automatic and always successful. Yang (2012), through her study on strategic coupling in Taiwan, Pearl River Delta and Yangtze River Delta, confirmed that the fortunes of regions are shaped not only by what is going on within them, but also through wider sets of relations of control and dependency, of competition and markets. In other words, such processes are highly contingent and unpredictable, and her findings on the role of national and local initiatives in China in enabling strategic coupling with global production networks are relevant for this dissertation.

Challenges and Critiques of the GPN Approach

Although the GPN approach has advantages over its antecedents, it is not without its own difficulties. Critics of GPN at the first-order level can be divided into four types. The first group includes those who have a very different standpoint on the network metaphor. For example, even though many GCC/GVC scholars, such as Ciccantell & Smith (2009), see the limitation of chain approaches, they still do not believe a network metaphor is more appropriate. A second group of critics includes those who think that some core ways of seeing should be either emphasised more or downplayed. For example, Glassman (2011) suggests that GPN should pay more attention to the role of geopolitics in structuring production networks. Similarly, Levy (2008) argued that GPN analysis is constrained by a rather economistic approach to power relations, and a narrow focus on extraction of rents, without revealing the wider institutions of power that underpin GPNs. These criticisms are, to some extent, valid: some economic geographers do tend to treat connectivity as a quantitative concept (more or less connected rather than focusing on how or why), while also failing to recognise the influence and significance of, for example, the security of sea lanes, global chokepoints (e.g. Strait of Hormuz and Strait of Malacca), pirates, terrorism, naval power projection and other geopolitical issues that significantly affect the location of firms, costs of transportation and the geographical configuration of production networks. Fortunately, given that GPN already pays a lot of attention to power relations, territoriality, multi-scalar institutions and varieties of capitalism, it does not in principle prevent a more geopolitical analysis.

A third group of critiques comes from those who are not satisfied with the explanatory power of the GPN approach. For example, Sunley (2008, p.8) questioned the network ontology underpinning GPN, suggesting that “this view of networks means that it often includes just about everything and lacks analytical boundaries and clarity”, and given the number of variables considered, GPN as an approach is often too complicated to either predict or explain phenomena. This is partly a valid attack, although it is not necessarily a failing: GPN theory, like many theories in social sciences, are not (and should not pretend to be) a scientific theory; instead they are theoretical perspectives that provide insights and frameworks and help us find order out of, or make sense of, ostensibly chaotic, random and contradictory phenomena. The fourth group of critics includes those who complain that GPN can only describe the status quo and that it has no clue about how the status quo emerged in the first place. For example, Starosta (2010) pointed out that GPN (and GCC/GVC) are inherently empiricist and only try to explain the nature of the system in relation to the existing power structure, without adequately explaining how that structure is produced and contested over time. This is not entirely true: GPN's emphasis on spatial embeddedness, discontinuous spatiality and path dependency includes some recognition of the historical geography of the current power structure.

C. GPN Concepts and Building Blocks

At the second-order level, GPN can be thought of as constructed by its concepts and building blocks. Three core concepts underpin GPN theory, namely value, power and embeddedness. At this level, few criticise the inclusion of these concepts, although the understanding of these concepts is not uncontested.

Value

Each stage in a production circuit, each node in a GPN, creates value through the combined application of labour skills, process and product technologies, and the organisational expertise involved in coordinating complex production and logistical processes and in marketing and distribution. Within GPN approaches, value means both Marxian notions of surplus value and more orthodox ones associated with economic rent (Henderson et al. 2002, Coe 2009, 2012). There are four significant points to make here.

First is the way value creation centres on two dynamics: the labour process and rent. On the one hand, value creationconcerns the labour process that converts labour power into economic power under certain conditions: this includes issues of employment, skill, working conditions, production technology and the social-institutional context in which they are reproduced. But critics, including Rainnie et al. (2011), argued that GPN, like its predecessor GCC, fails to consider labour as an active agent capable of shaping production structures and geographical organisation and treats labour as if they are “the passive victim of restructuring processes” (Cumbers et al. 2003, p.369). On the other hand, it also concerns the possibilities for creating various forms of rent. The issues here are whether a given firm can create rents from (a) an asymmetric access to key product and process technologies (technological rents); (b) particular organisational and managerial skills such as “just-in-time” production techniques and “total quality control” etc. (organisational rents); (c) various inter-firm relationships that may involve the management of production linkages with other firms, the development of strategic alliances, or the management of relations with clusters of small and medium sized enterprises (relational rents); (d) establishing brand name predominance in major markets (brand rents); (e) preferential access to natural resources (resource rents); (f) the impact of government policy (policy rents); and the nature of the financial system (financial rents) (Henderson et al. 2002; Coe 2009). Besides, Coe (2009) added three remarks about value creation: (a) rents require considerable investment over time, so they are cumulative and dynamic; (b) certain firms cannot create all of these rents; and (c) the form of value could be changed as value is transferred through GPNs. However, just as mentioned above, one could argue that the concept of value here is not “Marxist enough” or it is constrained by a rather economistic approach (Levy 2008).

Second, the aim of a firm is continuously to enhance value – to increase profits and/or to reduce competition—through a whole variety of means: product and process innovation, improved labour productivity, more efficient logistical systems, and so on. Four main issues are associated with value enhancement, including: (a) the nature and extent of technology transfers both from within and without the given production network; (b) the extent to which lead and other major firms within the network engage with supplier and subcontractors to improve the quality and technological sophistication of their products; (c) as a consequence, whether demands for skills in given labour processes increase over time; and (d) whether local firms can begin to create organisational, relational and brand rents of their own. In all of these cases, the national institutional influences to which firms are subject (government agencies, trade unions, employer associations, for instance) may be decisive for the possibilities of value enhancement.

Third, as Henderson et al. (2002, p.449) have pointed out, “it is one thing for value to be created and enhanced in given locations, but it may be quite another for it to be captured for the benefit of those locations”. The iPod case given by Dicken (2011, p.432) showed that the highest-value capture tends to be at the higher end of the value chain (design, brand ownership and control) whilst assembly is far less significant in the total value added. Geographically speaking, this means that the US captures most of the value, despite the fact that all iPods are actually manufactured in China (in Taiwanese-controlled factories) and the hard-disk drive is manufactured by the Japanese firm Toshiba but mostly in factories located in China and the Philippines (intra-firm spatial division of labour). The capturing of value leads to another core concept, power (discussed below). The fourth point concerns the negative externalities of production and the way production may create value but "also has the capacity—albeit unintentionally—to destroy value" (Dicken 2011, p.456). These externalities, according to Dicken, include (a) over-use of non-renewable and renewable resources; (b) over-burdening of natural environmental "sinks"; and (c) destruction of increasing numbers of ecosystems to create space for urban and industrial development. Other examples may include regional air pollution (a key issue in China and linked to intensive use of coal) which has a range of effects, including reduced labour productivity through damaging health, and motivating educated labour (whose geographical flexibility is higher) to emigrate (brain drain).

Power

With a GPN, power can be thought of as the ability of one actor to affect the behaviour of another actor regardless of the latter's willingness, although the consequences need not be contrary to the latter's interests (one does not need to assume that every actor knows its own best interests every single moment of the time, as the homo economicus assumption does). The GPN concept of power rests on three assumptions. First, that power is relational, meaning that power is not like a commodity that can be accumulated like money; instead it varies among actors in a GPN, the actors' relative position, the rents that they have at their disposal, the skill with which these rents are mobilised, and the skill and willingness with which power is employed. Second, power relations in supply networks are transaction specific. It means that power structures at a given point a GPN will affect and be affected those at other stages of the GPN. Third, any given set of inter-firm relations are not purely about power, as there is always a measure of trust, mutual interest and dependency involved (Coe 2009).

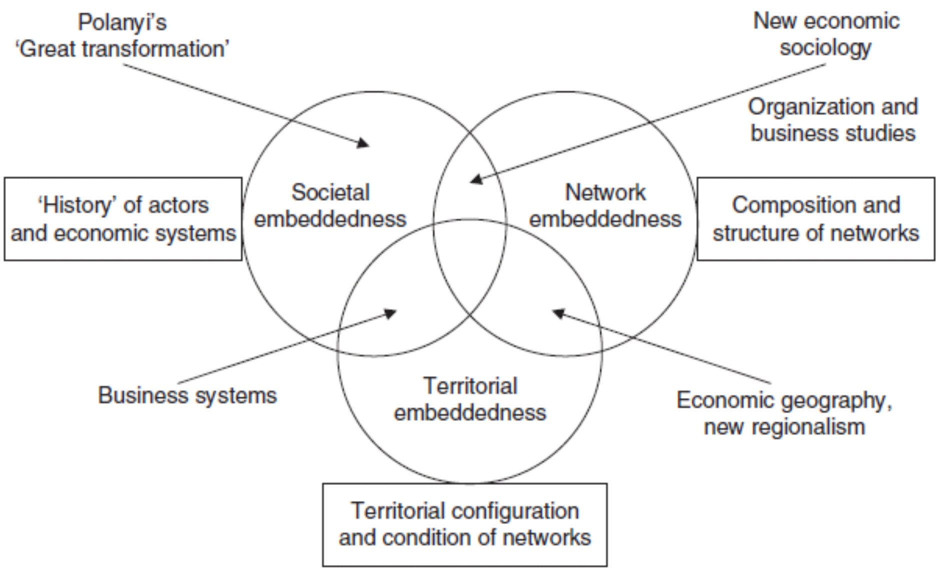
There are three forms of power that are significant here. The first form of power is corporate power. The lead firm in the GPN has the capacity to influence decisions and resource allocations – vis-à-vis other firms in the network – decisively and consistently in its own interests (Henderson et al. 2002). But it is important to remember that GPN theory rejects a zero-sum conception of power and the lead firms rarely have a monopoly on corporate power. The lesser firms are not the passive victims. Rather, lesser firms sometimes have sufficient autonomy to develop and exercise their own strategies for upgrading their operations. When we move to the governance structure later in this section, we will see there is a range of power topologies. The second form is institutional power. According to Dicken, Hess, Coe & Yeung (2002), the sources of this type of power include: (a) the national and (federal) local state; (b) supranational inter-state agencies (e.g. UN, EU, ASEAN and SCO); (c) supranational institutions (e.g. IMF, World Bank, the WTO); (d) the various UN agencies; and (e) supranational credit rating agencies (Moodys, Standard and Poor). There is another source too that Henderson did not mention, that is, (f) private sector standards put forward by "amorphous alliances of corporations, NGOs and civil society groups" (Giovannucci & Ponte 2005, p.298). The third form of power is collective power. By this form of power we understand the actions of collective agents who seek to affect companies at particular locations in GPNs, their respective governments and sometimes inter-national agencies. Examples of such collective agents include trade unions, employers associations, and NGOs concerned with human rights, environmental issues, etc.

Embeddedness

GPNs do not only connect firms functionally and territorially: they also connect together the specific social and spatial arrangements within which those firms are embedded, and which influence their strategies, and the values, priorities and expectations of managers, workers and communities alike. The way GPNs are grounded in place is both physical (in the form of the built environment) and also less tangible (in the form of localised social relationships and in distinctive institutions and cultural practices) (Dicken 2011). Indeed, emphasis on the notions of embeddedness is a distinctive feature of GPN analysis, alongside the governance, power and value dimensions that also characterise GCC/GVC accounts (Coe 2012). Like most theories used in human geography, the origins of the embeddedness concept are to be found outside the discipline of geography and can be traced back to the 1940s (Hess 2009). Since Granovetter's (1985) pioneering the concept of embeddedness within the field of economic sociology, it has become a ubiquitous term since then (Dicken 2011). Hess (2009) identified two major factors that contributed to the growing interest in noneconomic factors by economic geographers over the last two decades, Epistemologically speaking, economic geographers have been increasingly concerned about the limitations of mainstream approaches to economic geography and the "spatial fetishism" of the discipline—the tendency of treating social relationships as purely absolute spatial relationships. Geographers, therefore, called for a different ontology of space—relational space—as being socially constructed and shaped by human practices. Practically speaking, the traditional explanatory tools such as transaction cost theory or agglomeration economics have been giving way to noneconomic factors, including social capital, trust and embeddedness. A large body of work—known as "new regionalism" has evolved from this conceptual shift.

Different scholars categorise "embeddedness" differently, though this does not mean that their understandings of the nature of embeddedness have any fundamental conflicts. Hess (2004, 2009) drew a distinction between societal, network and territorial forms of embeddedness (Figure 2.4). In real-life geographies, however, these concepts cannot take effect independently, and instead all three forms of embeddedness shape networks and economic action in time and space. GPN's emphasis on embeddedness presents a valid and serious challenge to Castells (1996) and other hyperglobalists who believe that capital has become "hyper-mobile", freed from the "tyranny of distance" and no longer tied to "place", that economic activity is becoming "deterritorialised" or "disembedded", and that spaces of flows are replacing spaces of places. But as Dicken (2011, p.62) rightly observed, "the world is both a 'space of places' and a 'space of flows'. GPNs don't just float freely in a spaceless/placeless world".

Figure 2.4 Hess's Fundamental Categories of Embeddedness



Source: Hess (2004, p.178)

Societal embeddedness is formed by actors moving between places like migrant labor or transnational entrepreneurs and enterprises, corresponding what Annemarie Mol and John Law call fluid spaces. It connotes the significance for economic action of the cultural, historical and institutional origins of the actor concerned. This is the key observation around which the varieties of capitalism literature (mentioned above) plays out.

Network embeddedness mirrors the topology of relational space of networks, in which distance and proximity are not measured in Euclidian terms, but are a function of the relations between actors. It highlights the connections between heterogeneous actors (individuals and organisations) that constitute a GPN, regardless of their location, and is therefore not restricted to one geographical scale. It refers to functional and social connectivity within a GPN, the stability of its agents' relations, and the network structure.

Territorial embeddedness links to a notion of space as region and captures how firms and institutions are grounded or anchored in different places. For example, Barrientos & Smith (2007) assessed codes of labour practice in GPNs, and Nadvi et al. (2011) evaluate labour standards in the global sports goods industry. Work on the globalization of retailing and temporary staffing, for example, has emphasised the peculiarly high levels of territorial embeddedness in host markets that are required in order to secure competitive success. Liu & Dicken (2006) finesse this point further, dividing embeddedness into two types—active embeddedness and obligated embeddedness. This distinction is particularly useful distinction when addressing production activities in countries like China, where state regulations are more penetrating. Others have explored different territorial forms of embeddedness: using a case in the Philippines, Kelly (2009) suggested that local households and communities (the spaces of reproduction) should be considered territorially-embedded actors in regional industrial development as an essential complement to firms and governments.

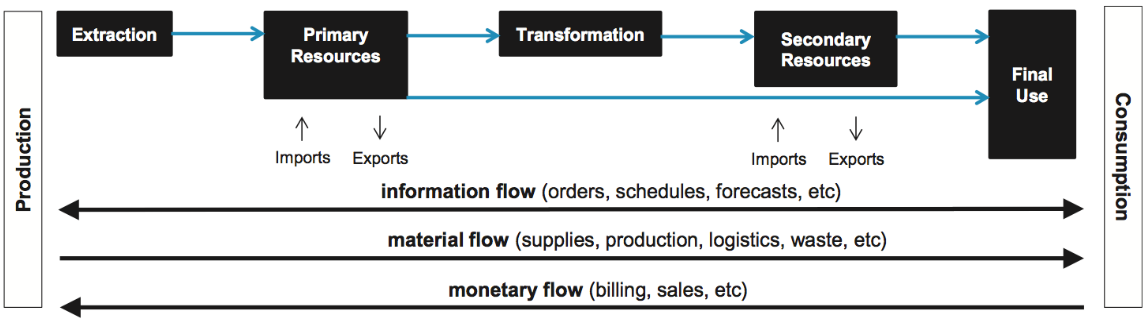
D. GPN Empirical Application

The third-order GPN denotes its actual application to empirical studies. The last ten years of work on GPN development have seen a vibrant expansion in the number and type of GPN empirical studies. The GPN approach has been adopted to understand functional and geographic integration in a wide range of industrial sectors. Most applications are concentrated within manufacturing, including aircraft (Bowen 2007), automobiles (Isaksen & Kalsaas 2009, Liu & Dicken 2006, Rutherford & Holmes 2007), electronics (Bowen & Leinbach 2006, Vind & Fold 2007, Yang 2007, Chen & Xue 2010), computer (Yang 2012), textiles (Tokatli 2008) and wood products (Murphy & Schindler 2011). Recent work has expanded the sectoral range to focus on extraction (Bridge 2008), producer services such as temporary staffing (Coe 2011) and logistics (Bowen & Leinbach 2006, Rodrigue 2006, Hesse & Rodrigue 2006), and the creative industries, such as animation (Yoon & Malecki 2009) and film (Lim 2006). This section reviews a few latest applications. The aim is not to be exhaustive, but to highlight several key arguments of recent supply chain/GPN literature that are relevant to our study of natural gas. First, the recent literature calls for a more comprehensive understanding of any supply chains by taking into account the extraction sector (in our case, gas extraction), i.e. the "beginning" of any chains. Second, instead of adopting a simple and linear imagination of supply chains, it highlights the transactions among different parts of a GPN through, for example, the concepts of "spaces of flow". Third, it identifies the possibility of the existence of separate, discontinued production networks of the same sector within the same region. Finally, it advocates a stronger sense of politics and geopolitics of GPN analyses.

Re-defining Chains: considering extraction and logistics

Although the work of Ciccantell & Smith (2009) owes more to GCC than to GPN, it calls for a "rethinking" of GCC in two ways that are relevant to this study of gas and are in line with some arguments put forward by GPN. First, the authors call for research on production networks to "lengthen the chains" by starting at the beginning, i.e. within extractive systems. It suggests the necessity of taking into account the spatial embeddednes of production, which traditional GCC studies largely failed to do so. They argue that "the local profoundly shapes the global in raw materials GCCs" given the "variety of other location-specific characteristics and processes shaping the strategies of global firms and national states to utili[s]e these resources" (Ciccantell & Smith 2009, p.362). These location-specific factors include, for example, "local geology, topography, hydrology, indigenous populations, conflicts over resource access, efforts to capture the benefits of extraction for local populations" (Ciccantell & Smith 2009, p.362). The authors illustrate the argument by comparing the oil extraction industries in Canada and Iraq. Despite the similarities of having large oil reserves, being under British imperial control in the past, being major locations of oil extraction for export for almost a century, the socioeconomic and geopolitical conditions of the oil extraction industries in these two regions have led to a radically different picture: despite its better crude oil quality, Iraq's oil sector remains less developed and stable than Canada. Second, they highlight the dialectical relationship between growing scale economies in production and an associated need to overcome diseconomies of space via scale economies in transportation. This is especially obvious in the production networks of gas: gas resources remain stranded and undeveloped until they can be transported to the consumers economically. Since the economics of transportation, either in form of LNG or pipeline, are so sensitive to scale, large markets are required to justify them, confirming the inter-dependence between economies of scale in production and economies of scale in transport (see also Bunker and Ciccantell 2005). Similarly, Hoggett et al. (2014) adopt a broader definition of a supply chain that goes beyond a uni-directional linear process; instead, information and money flows between production and consumption in both directions (Figure 2.5), and they highlight the role of institutions and embeddedness, as "[t]hese supply chains are shaped by the policies, institutions, regulatory frameworks and practices that are in place within a country, as well as the wider interconnections it has to other energy systems, and the markets, rules, and regulations that shape them" (Hoggett et al. 2014, p.2). However, both GCC/supply chain studies do not pay attention to the actors embedded and their relational networks at a variety of scales.

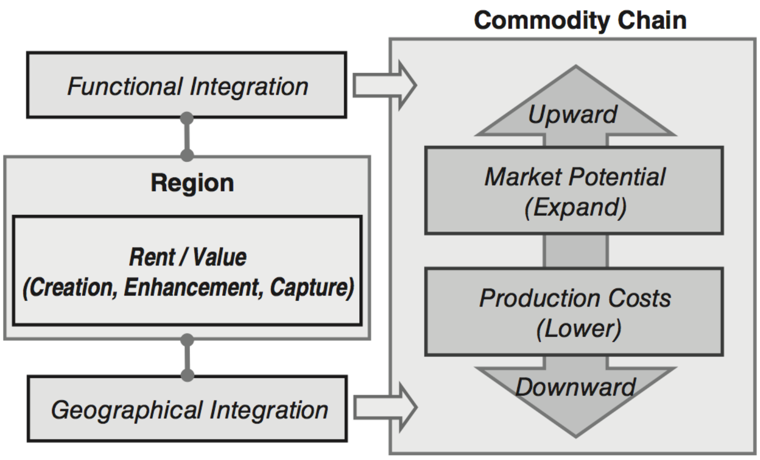
Figure 2.5 Energy System as a Supply Chain



Source: Hoggett et al. (2014, p.2)

Recent work has also sought to consider the role of transport in GPNs, and acknowledges how economic geography and transport geography have remained largely separated (Coe 2012). The work of Rodrigue (2006) represents a original attempt to close up the literature gap. Pondering the very nature of GPN, Rodrigue characterises GPN as a concept that "jointly expresses the locational, value generation, transactional, and distribution reality of the global economy". GPNs therefore, are "bound to the interactions of supply and demand, as they reconcile the material needs of the consumers (be it an individual or a corporation) to have the right product, in the right quantity, at the right price, at the right location, and at the right time, and the capacity of production and distribution systems to accommodate such needs" Rodrigue (2006, p.511). In other words, a GPN requires mobility to operate and may be considered "a space of flows" Rodrigue (2006, p.511). He argues that the relationship between transportation and GPNs are shaped by the paradigms of geographical and functional integration, and these "distribution strategies" Rodrigue (2006, p.510) seek to expand market or lower total production costs (Figure 2.6). Both geographical and functional integration help explain the dynamics of embeddedness, both as locational and organisational processes. Rodrigue's contributions are of interest to this study given the significance of "distribution strategies" to the gas sector.

Figure 2.6 Functional and Geographical Integration to a Commodity Chain



Source: Rodrigue (2006, p.512}

Multiple and Co-evolving Networks

Recent GPN literature is aware of the coexistence of discrete production networks of the same industry within the same region. Murphy and Schindler (2011), for example, applies the GPN approach to the wood products industry in Bolivia and seeks to understand how regional development processes in Bolivia are shaped by the trans-local connections afforded through the wood products sector. It distinctively points to the fact that different production networks within the same sector can co-exist and co-evolve in the same region. By comparing networks of production involving high-volume buyers (such as TNCs) and those serving low-volume international buyers, the authors emphasise the discontinuous and "polycentric" character of production networks. They also highlight the different ways in which these two networks create, enhance and capture value, and their implications for strategic coupling and regional development. They argue that the ways in which relational proximity translate into the value-creation, enhancement and capture processes vital for regional development depend on the particular kind of production network relationship available to firms in a given region. They summarise four discontinuous production networks embedded within Bolivia's wood products industry, resulting from their differences in accesses in resource, capital, market and technology. Their discussion inspires this research to pay attention to the possibility of different types of production networks within China's gas sector, and their vertical and horizontal relations.

Towards a more "political" GPN

There have been calls to integrate a wider understanding of geopolitics into GPNs. Approaches in political science and international relations – traditional geopolitics, in other words – is often limited by state centrism, an approach that regards the state as a coherent and unified actor. Glassman (2011) acknowledges the contribution of a GPN approach to overcoming of such state-centrism, "opening a potential space for interrogating political processes as integral aspects of production" (Glassman 2011, p.154). His criticism, however, is that most work on GPNs has avoided discussion of the political issues that "speak to the messiness, contestation, and violence that often accompanies globali[s]ation" (Glassman 2011, p.154). He claims that the major geopolitics issues, like war, are missing within the GPN literature. By investigating the case of South Korea, he proposes a geopolitical economy approach to GPNs, which includes consideration of war, violence and geopolitics to extend the understanding of globalisation. Critical geopolitics has been pushed beyond traditional state-centric concerns toward engagement with a wide variety of issues at a scale beyond the state level, but to Glassman, what is lacking in GPN studies, is the narrower, more "traditional" geopolitics angle, covering issues from local conflicts to international politics. His point is that the agents and agencies found in geopolitics are not exterior to GPNs but in fact play central roles in the constitution of such networks. There are good reasons for a wider consideration of the state's role in GPNs, and in the energy sector in particular. The resource war thesis, for example, might be narrow in its perspective, but it illustrates how the state is central to the organisation of natural resources and how the links between energy and economic and political power mean it is often deemed a strategic commodity. In China's gas sector, securing gas imports - especially pipeline gas from Central Asia, Myanmar and Russia - is achieved by traditional state actors (central governments or political leaders) and driven by political considerations.

Re-politicalising GPNs, however, should not be confined to the traditional state scale. Levy (2008) calls for integrating political contestation to GPNs. Levy argues that mainstream approach to GPNs still largely "revolve around economistic considerations of location-specific advantages, such as factor costs and market access, and firm-specific advantages, such as technological and marketing expertise" (Levy 2008, p.945) and, as a consequence, these purely economic accounts "offer an inadequate portrayal of the complex ways in which market forces themselves operate within, as well as shape, social and political contexts" (Levy 2008, p.946). While one does not need to fully agree with Levy's judgement that most GPN studies are totally economistic, Levy's contribution is to identify how GPNs are more politically contested fields. Importantly, political contestation takes place not only at the state level (such as in the form of regulation), but also at the firm level (such as market power manipulation). In fact, the concepts of power and value (rent) are already fundamental to a GPN approach. Levy's point of view is important to energy and is even more so to the case of China, given its stubborn authoritarian nature and the dominance of national oil companies.

2.1.3. Summaries

Having reviewed the literatures on energy geography and global production networks, this section makes some concluding comments regarding the approach adopted in this dissertation. This chapter has shown how work on energy has broadened its focus from rational management, often a top-down approach to "rationalising" siting of centres of energy supplies and demand in order to maximise efficiency and minimise risks, towards governance, which stresses multidimensional and multi-actor interactions. It has displayed how the focus of the work on energy scarcity has been widened to consider the significance of social-economic factors for energy consuming behaviours. It has deconstructed the process of energy transition and reviewed the development of this concept from a simple "energy ladder" representation towards the multi-actor, multi-scalar and multi-system perspective. It has found that some contemporary work on global energy governance calls for researches that pay more attention to actors and embedded institutions, an argument similarly put forward by GPN approach. It has also reviewed work on energy security that encourages a broader understanding of energy security by considering not only the national dependency on energy imports, but also domestic resilience and robustness of energy supplies.

The chapter has also reviewed work on production networks and chains in economic geography, and outlined the core elements of this approach. Overall, this chapter has shown how there is considerable scope for adopting a GPN approach to understand the geographies of energy transition. The GPN approach to regional political economy reflects the premise of new regional geography that a "region" is more than a bounded spatial container with "idiographic" details but is, instead, a porous space constantly shaped by internal and external forces at a variety of scales. Rather than merely gathering, organising and presenting regional "facts and figures", the GPN approach seeks to capture the less observable "structures" through which energy economies unfold in a relational manner. Moreover, while energy has typically been considered as an industrial input or factor of production, contemporary research on the geographies of energy increasingly sees energy from the beginning (i.e. extraction) or even identifies it as a commodity, which is underpinned by a set of man-land relations or a social transformation of nature (the so-called "geographical political economy" approach). Empirical applications of the GPN approach to the energy and resource sector are still rare, but its relational understanding of commodificaiton and notions of value, power and embeddedness make it well suited to making sense of the structure taking shape around energy. The GPN's dialectical understanding of different parts of a commodity chain echoes the idea that no component of the commodification process (from upstream to downstream) can be understood separately from the other components. While GPN is a very flexible device, it does not provide a detailed set of conceptual tools that are tailor-made for the energy and resource sector. Application of GPN to gas, therefore, requires careful attention to the material, technological and institutional specificity of gas.

2.2. Research Design

2.2.1. Research Perspective

This study contributes to a line of scholarship that may be characterised as geographical political economy (GPE), and which has dominated Anglophone geographers' approaches to studying economic geography since 1980. This school of thought prioritises commodity production over market exchange, and holds that disequilibria are normal (Sheppard 2011). GPE assumes that commodity production entails the transformation of 'natural resources' into other material and immaterial objects in order to create value. Such commodification is entangled with biophysical, social, political and cultural processes (Castree 2003) and is always a highly politicised process in which pre-existing power inequalities operate at a variety of geographical scales (Bridge & Le Billon 2012).

Epistemologically, this study is broadly in line with the tradition of critical realism and relies on both quantitative and qualitative methods. Critical realism as an ontology recognises how the world observed by the researcher undergoes a continuously dynamic process of structuration, as actors interact with structures and vice versa (Yeung 1997). It puts particular emphasis on the roles of actors in an environment, and their abilities to influence the structures in which they are embedded, as well as on the mechanisms for adjustment (Sayer 2000). It also argues that social structures are transformed and reproduced by social actors (Yeung 1997).

Methodologically speaking, critical realists would advocate the use of qualitative research methods in order to disclose processes that are not directly observable. This approach, however, is often paired with quantitative data. By employing a critical realist perspective for this research I seek to develop a critical investigation of the structures and processes involved in producing "regional" or trans-local production networks of natural gas in China. Relying purely on quantitative research methods would risk overlooking how the "variables" under study are socially and culturally constructed, and would make it difficult to access and reveal economic and social processes (Silverman 2000). Qualitative research provides a more in-depth and richer understanding of social phenomena than a purely quantitative piece of research could provide; however, in some cases quantification can be useful and indeed necessary in the study of energy, which is fundamentally a physical and measureable phenomenon (Bhaskar 1989). There are two other reasons why using purely quantitative methods - with the currently available energy statistics – would fail to fulfill the objectives of this dissertation. First, available energy statistics from domestic and international sources are almost entirely organised nationally or regionally; firm-based statistics are less readily available. Second, economic geographers tend to agree that sectors and industries are shaped not only by economic and physical factors but also by a number of non-quantifiable—or less quantifiable—factors, such as embeddedness, power topology and intangible knowledge. This holds particularly true for the energy sector, which is often perceived, regulated or run by the state as a strategic industry and shaped by diplomacy, geopolitics and national security policy. This statement is even more valid in the case of China, featuring authoritarian capitalism in which state policies and non-market forces play a large part.

Hence, this study makes use of secondary data and qualitative research methods, mainly semi-structured interviews, in order to uncover the underlying structures and processes behind observed quantitative phenomena (such as the level of gas consumption or the structure of the fuel mix, for example), unmask the subtle validity of some prevalent discourses and unearth a richer understanding of the complex and dynamic production networks of China's natural gas industry. After considering all these factors, the GPN approach offers a generic heuristic framework that is approprirate for carrying out this study. It is flexible enough to allow both quantitative and qualitative methods to work together; it is comprehensive enough to take into account the often overlooked key factors of commodity chains such as sub-national variations, intra-firm organisation and spatial embeddedness; it is tolerant enough to accommodate a high level of sector and geographical unevenness; it is systematic enough to consider quite subtle and sometimes seemingly random developments such as the shift of business cultures (especially in authoritarian country like China); and it provides a multi-actor and multi-scalar framework with which to explore the highly dynamic networks of the intra-, inter- and extra-firm interactions.

2.2.2. Secondary Data and Primary Fieldwork

This study relies on secondary data to illustrate and analyse the overall structure and spatial and temporal trends within the energy sector in China. In doing so it acknowledges the limitations of available data, of which a lack of firm-based data and the inability of current data to quantify subtle variables, such as business trust and diplomatic ties, are the most significant. The secondary data used in this dissertation come primarily from the Chinese government and international energy institutes, such as the International Energy Agency and BP's Statistical Energy Review. In terms of domestic sources, this study owes a great deal to the China Premium Database (provided by CEIC, a company; I had access to China Premium Database because Chinese University of Hong Kong, at which I worked as a visiting lecturer during my fieldwork, had subscribed it) and China Energy Databook Version 8.0 (freely distributed online by US Department of Energy's Lawrence

Berkeley National Laboratory). Both databases collect statistics directly from the Chinese official sources, such as the China Statistical Yearbook and the China Energy Statistical Yearbook and update the data monthly. There are often 1-2 years time lag, therefore most of the data used in the study are of 2011 or 2012, but I have managed to update them to 2013 whenever possible.

The fieldwork was designed to carry out semi-structured interviews with corporate and state elites along the gas supply chain in China. The interview was selected as the most appropriate qualitative method of data collection, as although it might be possible to access more respondents through a survey method, the interview is the only way to engage with important actors in the sector and develop an understanding of the characteristics and relationships within the natural gas industry. It reflects, therefore, the view of (Kvale 1996, p.14) who has argued that interviews can act as "construction sites" for generating knowledge and understanding. The semi-structured interview is one of the most common qualitative research methods employed in much social studies and is increasingly recognised as a suitable method for interacting with firms and organisations (Schoenberger 1991). There are several benefits of using semi-structured interviews with key themes and suggested questions as a guide, including allowing for exploration of points that may not have been considered before or may be unique to a particular agent, industry or country. Another advantage of interviews over surveys is that it is more likely respondents will consider the full range of questions,: psychologically-speaking, participants tend to be much more responsive during a face-to-face interactive meeting than doing an one-way structured survey (Sarantakos 2005).

The issues associated with elite interviews also need to be addressed here. The capital-and-knowledge intensive nature of the natural gas industry suggests that many of the subjects involved in interviews are likely to be what are classed as “elites”. According to Wood (1998), elites are those who have privileged access to, or control over, particular resources that may be mobilised in the exercise of power or influence. They are linked by network or social or professional relations, and they are socially and discursively constructed as an elite, either by themselves or others. Cormode & Hughes (1999) highlighted how researching these powerful elites presents different methodological and ethical challenges, such as the difficulty in securing access to interview them, and the unintended influence of the positionality of the researcher in terms of race, nationality, age, gender, social and economic status and sexuality on the information given by the elites. For the former case, Welch et al. (2002) suggested that obtaining a “port of entry” to the environment inhabited by elites is best conducted through an institutional referee who is close to those elites. I was fortunate in that several Hong Kong- and China- based academic institutes facilitated research access: visiting scholarship positions enhanced elite perceptions of my positionality, and their willingness to accept an interview. However, I also learned that sponsorship and introduction were not, on their own, sufficient: if, in making introductions, a sponsor did not explain clearly the intention of the research, a potential meeting could be refused or canceled.

Because of my identity as a male Chinese researcher, potential problems associated with interviewing elites in China were less pronounced. But as a young researcher, the power relationship between the researcher and the subject is undoubtedly asymmetrical. To somewhat overcome any potential concerns around the power relationship between the researcher and the subject it is important that enough preparation is completed for each interview to be able to explore the issues outlined in the plan for the interview effectively (Hoggart et al. 2002). It is also essential to keep in mind that the perceived positionality of the researcher may shift with a change in the social environment. A more sociable locale, such as a cafe, usually narrows the power difference between a researcher and the elites, compared with, for example, the offices of the elites. I found interviews with elites conducted in a restaurant, cafe or pub to be most effective.

Interviews were conducted in the mother tongues of the respondents – either Mandarin, Cantonese or English – so that they were more willing to participate in the research, and more likely to provide subtle and richer insights. Although I do not speak standard Mandarin, I had no practical difficulties communicating well with elites; interestingly some respondents considered that my heavy Hong Kong accent was a bonus, as it constructed a perception of me being a "foreign expert". I also quickly learned that, when doing fieldwork in China, interviewers should not jot, note or record any conversations. This is primarily related to cultural practice, and has little to do with trust. Following standard ethical review procedures I informed interviewees beforehand that their names would not be quoted and their comments would not be used for non-academic publications. I chose to jot down key observations and comments right after the meeting and send it to my email account for the purpose of backup.

The fieldwork lasted nine months, from September 2012 to June 2013, in Hong Kong and Beijing, and was partially financially supported by the University of Manchester and a Royal Geographical Society (with IBG)'s Postgraduate Research Award. The part-time salary I earned from teaching at Chinese University of Hong Kong also supported the fieldwork. The reasons to select Hong Kong and Beijing to be the sites of fieldwork are mainly practical; the original plan was to include Sichuan, China's traditional gas production centre and current frontier of shale gas exploration, but it had to be aborted due to financial constraints. I began my fieldwork in Hong Kong, because I grew up in this city and had established some networks with the local energy companies through my previous studies at Hong Kong Baptist University and my association with Hong Kong Energy Studies Centre. Many major gas firms operating in China are listed in Hong Kong: for example, Towngas Hong Kong is the one of the largest gas distributing company in China. During an energy seminar held at Hong Kong Baptist University, I was introduced to a senior policy-maker from the National Development and Reform Commission (NDRC) of the Chinese government, who later introduced a number of key informants from the NOCs and IOCs when I moved to Beijing. The reason for visiting Beijing was that, as the capital and political centre, it is where key officials, influential scholars, lobbyists and decision-makers of Chinese energy firms and other international energy firms are located.

Developing a rigid sampling frame for interviews, particularly in the political and economic realms, proved extremely restrictive for the research (Yeung 1997). In practice my sampling relied on (i) establishing contact with informants within my established network, often via referral, (ii) cold calling, (iii) attending professional conferences, and (iv) a snowballing technique, whereby I requested that interviewees identify further subjects from their acquaintances that would be useful to the research. My association with the Centre for Energy and Environmental Policy Research (CEEP) at Beijing Institute of Technology proved to be extremely helpful in this regard, leading to introductions to government and national oil company (NOC) informants (CEEP used to be part of the CNPC/PetroChina research group and many of its PhD graduates are hired by government departments, e.g. National Energy Administration (NEA), and NOCs). The potential for bias compared with theoretical sampling should, therefore, be noted. The difficulty of cold calling elites in the political and business sectors came primarily from how to find their direct contacts, either phone numbers or email addresses, as this information is very often not publicly available. The way I adopted to get around it was to create an online LinkedIn Premium account as, with it, I could have access to the personal email addresses of many industry elites and their professional titles or positions. Although not all their comments are cited in this study (and only those being cited would appear in the appendix for the sake of simplicity), almost all interviews helped confirm or challenge initial ideas about China's gas 'problem' distilled from literature. In addition to those from the academic sector, a total of 37 elites from the industry or the government have been interviewed, as shown in Table 2.1:

Table 2.1 Summary of Interviews with Government and Corporate Elites

Names of Institutions	Number of Interviewees	Date	Location
Beijing Gas	2	Apr & Jun-13	Beijing
BP China	1	Apr-13	Beijing
China Gas Association	1	Jun-13	Beijing
China Gas Holding	1	May-13	Beijing
China Light Power	1	Sep-12	Hong Kong
China United Coalbed Methane	1	May-13	Beijing
CNOOC Group	4	Mar-Jun-13	Beijing
CNPC Kunlun Gas	1	May-13	Beijing
CNPC Trans-Asia Gas Pipeline	1	May-13	Beijing
CNPC/PetroChina (Upstream)	8	Mar-Jun-13	Beijing
Eni	1	May-13	Beijing
Hong Kong and China Gas	1	Sep-12	Hong Kong
National Development and Reform Commission	3	Mar-Jun-13	Beijing
National Energy Administration	1	Jun-13	Beijing
North West Shelf Australia LNG	1	May-13	Beijing
Sakhalin Energy Investment Company	1	May-13	Beijing
Schlumberger China	1	May-13	Beijing
Shell China	1	May-13	Beijing
Sinopec Group	4	Mar-Jun-13	Beijing
State Grid	1	Apr-13	Beijing
Wood Mackenzie (Beijing)	1	May-13	Beijing

2.3. Conclusion

The first section of this chapter has reviewed the literatures on energy geography, including work on energy as a factor of production, energy scarcity, energy transition, energy governance and energy security, as well as GPN as an approach within economic geography. These works have inspired the design of this research, and the following chapters explain how different actors are functionally, organisationally, institutionally and politically connected in realizing a natural gas transition in China. Inspired by the emphasis of the GPN approach on power, institutions and embeddedness, Chapter 3 unpacks the multiple roles of the state in China's gas transition, at different scales and locations. This "relational landscape" sets the scene for subsequent chapters. Chapter 4 investigates the "beginning" of China's gas supply chains by looking into the country's acquisition of gas through domestic production and imports. Reflecting the discussions in this Chapter (Chapter 2) on the social-economic dimensions of energy scarcity, the integration of inter-firm, intra-firm and extra-firm analyses into supply chain studies and the significance of traditional geopolitics within production networks, Chapter 4 examines how these above-ground factors shape the challenges and opportunities of China's gas acquisition. It draws on case studies of shale gas, coalbed methane (CBM), transnational gas pipelines and LNG imports. Chapter 5 explores the problems of gas distribution within China, which are vital to the robustness and resilience of gas security. It highlights significant differences between three domestic distribution modes, namely regional transmission pipeline, local distribution pipeline and inland LNG, and how gas prices are determined at different stages or via different modes. In short, this chapter seeks to understand how this multi-network gas distribution system works. While Chapters 4 and 5 are related to gas supplies, Chapter 6 is about gas consumption, which is shaped by government policies, infrastructure, relative prices of gas, and changing consumption practice and culture in different sectors. Finally, the second half of this chapter has explained why both quantitative and qualitative data are needed in order to fulfill the purpose of this research, how these data were collected, and limitations of these data as well as the research itself. These data are used in all of the subsequent chapters.

Chapter 3 Institutional Context

3.1. Introduction

This chapter unpacks the institutional context of China's natural gas production network. It describes this context as a "relational landscape" and highlights its implications for gas acquisition (production and import) (Chapter 4), delivery (Chapter 5), consumption (Chapter 6) and the value-creation and development strategies of actors in and across space. The chapter mobilises the GPN framework to examine the network of firms and states through which gas is located, extracted, processed, distributed and consumed. It highlights how economic relationships at the heart of this network of actors are shaped by China's political governance structure, in which a range of state actors and institutions play an important role. The GPN approach is well-suited to this task as it seeks to capture "the full mesh of relationships that lies behind any economic activity" and illustrate "the governance of production networks" by examining how such networks function, and the way in which some more powerful firms control or drive the overall system (Coe 2008, pp.318, 327). In other words, GPN as a framework not only investigates the complex combinations of internal (intra-firm) and external (inter-firm) networks connections, but it also pays particular attention to the "broader financial and regulatory systems" (Coe 2008, p.318) in which these connections are embedded, and invites the study of the non-firm actors (extra-firm networks) such as the state and its various institutions. These extra-firm networks constitute what GPN researchers would call "the institutional context of production network" (Coe 2008, p.332): it is the institutional context of gas production, distribution and consumption that is the focus of this chapter.

Following this introduction, the chapter reviews the common characterization of China as a "state capitalist" regime, and argues why analysis of the "state" is central to any GPN or energy study on China. After summarising the comprehensive role of the state in the gas sector, it proposes an "intra-state" point of entry for GPN analysis, given the range of state actors and scales involved, and their relative lack of coherence. The chapter highlights three state actors - central government, local (provincial) governments (and its local gas firms), and national oil companies (NOCs) – although it also discusses the penetrating networks of the Chinese Communist Party (CCP, the founding and ruling political party of the People's Republic of China), which has remained a "black box" to any GPN analysis so far. The chapter then traces back the historical evolution of the institutions that govern energy in China, and underlines the fact that, unlike in the command economy era, there is no longer a powerful, united central authority to govern China's energy or gas network. Given that the central government, including the energy governance group, has become increasingly fragmented and self-bargaining, the central-local power and control relationship is changing. The chapter goes on to explain why the power balance appears to be increasingly tilted towards local actors. Adding to this already complicated central-local politics, the chapter reviews the origin of the rise of NOCs. It investigates how NOC dominance has created a type of relational landscape in which local, private and foreign gas players have been forced to adjust their strategies to create, enhance and capture value and how, as a result, how NOCs shape the structure of China's gas production network. One of the contributions of this chapter is to unpack the "black box" of NOCs by focusing on their governance and ownership structures and relationship with the central government, which cannot be understood without knowledge of China's party-state system.

3.2. The Multi-faceted Chinese "State"

3.2.1. State Capitalism

Edward Said argued that the culturally-constructed notions of Occident and Orient carve out an "imaginative geography" structured on difference (Said 1985). This "imaginative geography" is still commonly found in the majority of popular and even international relations literatures dealing with China. They see China as a single-minded monolith and stubbornly favour the "essentialist and orientalising meta-narratives" regarding the role of the state (Gonzalez-Vicente 2011, p.402). Political geographer Ruben Gonzalez-Vicente vividly depicts how:

> On this count, the word 'China' is rarely disaggregated and on the contrary is often used to refer to things as different as 'China's central government', 'Chinese state', 'Chinese firms', 'China's foreign policy makers', 'China's industrial policy makers', and in some cases even 'Chinese people', assuming unified aims and strategies among this wide range of actors (Gonzalez-Vicente 2011, p.403).

The critical geopolitics literature, however, argues against these conceptualisations. It highlights how these cultural or social constructions serve to reproduce patterns of political power, and rejects the realist "assumption [about the link between state and territory] that there exists either complete and 'absolute' sovereignty or no sovereignty at all" (McConnell 2009, p.344). Contemporary economic and political geographers have made significant contributions to investigating the "territorial unevenness and local variation of the Chinese state in its relationship with inward investment" (Gonzalez-Vicente 2011, p.403). For example, Kean Fan Lim explains how the China's central government established Special Economic Zones (SEZs) for the "spatial fixing" of overseas capital (Lim 2010, p.680), marking how state and market are not contradictory forces in contemporary China but they are instead embedded in complex ways. Henry Wai-chung Yeung notes how the transnational operations of Singaporean firms in China are "embedded in dense networks of social and political relationships" (Yeung 2000, p.809) and how the re-scaling of China's political economy has empowered local authorities to significantly reshape everyday state-business relationships.

The scholarship of "varieties of capitalism" (VoC), one of the roots of GPN approach, contests the idea that there is a capitalism that is constituted of transhistorical and universal components (Power et al. 2012). Even in the post-Mao era, it is not unanimously agreed that the institutional setting, or the state system, of China, can be considered "capitalist", or "a new variety of capitalism" (Lin & Milhaupt 2013, p.699), although there is a growing consensus that China is becoming "functionally capitalist" (Peck & Zhang 2013, p.367). Although the aim of this chapter is not to determine the extent to which China is a capitalist regime, it agrees with a basic insight of the GPN approach that one should pay particular attention to the extra-firm, institutional settings of the political-economic system of a given country. Lin and Milhaupt (2013, p.700) agree that China's economic system, particularly the organisational structure and broad governance regime, remains largely a "black box" to the corporate governance literature. By evaluating the GPN approach as a methodology for studying Greater China, Henderson and Nadvi (2011, p.288) note that GPNs "link different types of firms embedded in different social and institutional contexts – that is, different forms of capitalism – and these different forms have different 'gearings' in terms of their capacity to capture value."

Recent studies loosely classify China as a state capitalist regime because of the way government and its state-owned enterprises (SOE) remain dominant in the domestic Chinese economy. This is especially the case in certain "strategic industries," including energy, even though China is now a member of the World Trade Organisation (WTO), an inter-state governance regime that embraces liberal market logic. The Economist (2012c) illustrates this general pattern by pointing out how the government is the biggest shareholder in the country's 150 largest companies, and how it structures the market by managing its currency and channeling money to favoured sectors The total assets of these SOEs equalled 62 percent of China's GDP in 2010 (Lin & Milhaupt 2013, p.735). Furthermore, the Organisation Department of China Communist Party is responsible for selecting top managers of the SOEs, and in turn some SOE managers hold key positions in government and the party (Lubman 2012). The relations among government, party and SOEs together have formed dynamic, diverse and dense networks embedded in any production network within the territorial space of China. Peck and Zhang (2013) similarly point out how the VoC scholarship sheds light on China's "distinctiveness of national capitalisms" (p.361) which reside in "the 'complementarities' between a complex of institutions with remits in financial and corporate regulation, education and training, and industrial relations and the labor market—which fuse and adapt to evolving patterns of economic behaviour" (p.361).

China's complexity as a "strange case" results from a particular type of "neo-liberalism" combined with "authoritarian centralised control" (Harvey 2005). Debates surrounding the "China Model" in political science similarly highlight how China's political economy deviates from neo-liberal development, although the level of such deviation is still under debate (Breslin 2011). Tackling the question "how neo-liberal is China's reforms", Wu (2010) holds that China's development model departs from that of the so-called "developmental state", which emphasises the strategic use of industrial policies and banking support to guide national economic growth, often in the context of late industrialisation. In China, however, the role of the state has shifted from that of "resource distributor" to "active market agent" after the political-economic reform" (Wu 2010). The implication for GPN analysis of the state being an active market agent – in other words, the economic dominance of SOE including NOCs – is that "Western-centric views on GPNs are likely to be challenged" (Henderson & Nadvi 2011, p.285).

Unpacking the role of state is vital to any GPN research because the primary question is not "where and how much value is created within the GPN", but "how much of it is captured in a particular location" (Henderson & Nadvi 2011, p.288). Understanding the underlying character of contemporary Chinese state capitalism is especially crucial because it largely pre-defines the winners and losers of the value-adding processes in the gas industry. For example, SOEs are exempt from anti-monopoly enforcement and the government "enforces rules selectively, to keep private-sector rivals in their place" (The Economist 2011) and block foreign firms from acquiring local firms (Lubman 2012). As a result, a private or foreign gas firm that has established a rich network of contact with governments at different levels is more likely to create and capture higher value. This networked embeddedness encompasses both corporate networks and the notion of "*guxia*", referring to relationships among individuals.

3.2.2. Comprehensive Roles of the State

In his famous economic geography work, Dicken (2011) reiterates that the "state" still matters a lot even in the globalising era. Before unpacking more complicated intra-state dynamics in China, it is useful to provide an overview of what roles the state plays in the gas production network.

A. Planner and Regulator

The state in China has played an essential role in shaping the national energy development via national policy and measures. Historically natural gas has been largely a regional fuel in China. The country started producing natural gas in 1949, but for a long time the Sichuan Basin was the only major gas-producing region. The beginning of China's "national" natural gas industry was essentially state-led. China did not have a "national" gas industry until the operation of the West–East Gas Pipeline in late 2004, which was planned by the state and constructed by CNPC. The latest grand thinking and strategy for the energy economy can be found in the government's FYP. The FYP often contains national quantitative targets. The current 12th FYP (2011-2015), for example, has stated or reiterated three major targets that need to be met by 2015: to reduce the energy intensity of the economy by 16%; to increase non-fossil fuel energy to 11.4% of total energy consumed; and to cut the carbon intensity by 17% (Houser 2013). In regard to natural gas, a number of significant policies were put in place in 2012 in order to shape the fledgling gas industry and market. Among the most important are China Energy Policy 2012 (a.k.a. China Energy White Paper 2012), the 12th Five-year Plan (FYP) for the Natural Gas Industry, the 12th FYP on Urban Gas, the 12th FYP on Shale Gas, the Natural Gas Utilisation Guide 2012 (renewed and revised from the 2007 version), and the Guideline on Encouraging and Guiding Private Capital in Energy Sector Investment.

Given that China's largest contributors to GDP and energy consumption are SOEs, these top-down policies and measures can sometimes be quite effective. For example, the 2007 and 2012 versions of Natural Gas Utilisation Guide, published by the National

Energy Administration (NEA), categorised all types of gas usage and ordered them into four groups: "prioritised", "allowed", "restricted" and "prohibited". Since the government aimed at prioritising non-industrial gas use, it has set higher gas prices for the industrial sector (except for chemical fertiliser manufacturer), even though gas transportation and distribution costs for the bulk industrial sector are higher than for other users (reflecting sectoral differences in transportation economies of scale). This contrasts with the situation in the U.S. where gas prices for the residential sector are generally higher than those for industrial sector. As a result the industrial and petrochemical sectors, although still the largest users of gas, have seen their market share drop from 82.5 to 44.6 percent during 1995-2011(CEIC 2014). In the *Natural Gas Utilisation Guide 2012*, the central government for the first time encourages natural gas as a transportation fuel. National targets sometimes fails to be met. For example, the state has set targets of producing 6.5 Bcm of shale gas by 2015, but this is now unlikely to materialise due to a variety of technological and institutional constraints, especially the regulation of gas pricing.

In China, the state sets prices for gas more strictly than for oil: while upstream crude oil pricing has been unregulated since 1998 (Li & Leung 2011b), pricing regulation is prevalent in almost every aspect of the gas commodity chain. The central government, mainly via the National Reform and Development Commission (NDRC) and Pricing Department, is responsible for setting wellhead and ex-plant prices of domestic gas, as well as pipeline transportation fees, that are, ideally, low enough to maintain the price competitiveness of gas and high enough to maintain an incentive for gas producers. The local governments, however, are responsible for setting provincial end-user prices that are low enough to avoid popular protest and switching back to coal, but high enough to maintain the basic profitability of distributing gas companies (most of which are either partly or wholly owned by local governments) in order to carry on local gas infrastructure development.

There are also regional differences in gas pricing. While most provinces adopt the "cost-plus" pricing formula, the central government launched a pilot gas price reform in the southern provinces of Guangdong and Guangxi at the end of 2011, where the natural gas price is linked to imported fuel oil and LPG instead of to the cost of gas production (see Chapter 5). The government also assigns a price reference point for each province. Prices for pipelined gas and LNG are differently set too, and the gap between them has constituted an economic rationale for gas firms to promote and see LNG/CNG as transport fuels, as selling them increases profits for both sellers (LNG prices are higher than pipelined gas) and buyers (LNG is cheaper than oil products) in some regions. The increasing share of dearer imported gas in the Chinese pipeline, however, is making China's regulated pricing increasingly difficult and ineffective.

Finally, there are several government agencies with regulatory jurisdiction over the domestic petroleum industry. For example, upstream oil and gas extraction licenses are issued by the Ministry of Land and Resources (MLR); and new refineries or chemical factories of any significant size must be approved by the National Energy Administration (NEA) and NDRC and are subject to the Ministry of Environmental Protection (MEP)'s Environmental Impact Assessment (EIA). The Ministry of Finance collects a resource tax on upstream extraction.

B. Landlord

The state can be seen as a "landlord" that owns and controls the country's gas resources. As a landlord, the state decides who can obtain access to the resources, at what cost, and in what quantity. In most countries around the world, it is mainly national governments that own mineral resources. Even in the capitalistic societies where private landlords or communities frequently own the surface of a land, strategic mineral resources of the "subsurface" most often belong to state governments. The US constitutes an exceptional case in this regard as hydrocarbons, except those on federal lands, are not reserved to the government but to the public (Bridge & Le Billon 2012). In socialist states such as China, all lands and their underground resources belong to the state according to law. In December 1950, the State Council promulgated the Regulation on the Mining Industry in the People's Republic of China, which specified that the country's mineral resources, including oil and gas, were state assets and should be managed by the central government (Zhang 2004). The MLR oversees the surveying, planning, management, protection and sustainable use of China's natural resources, including natural gas. It also issues licenses for exploration and production (Downs 2004a). National policy and political considerations play a critical role in determining who can have access to the resources (e.g. domestic versus foreign firms, and state-owned versus private firms), which resources are available for extraction and where (subject to environmental concerns for example), and the financial and other conditions attached to access (e.g. royalty payment, local content requirement, etc.). According to the Foreign Investment Industrial Guidance Catalog (2011 edition) issued by NDRC, only selected NOCs and their production-sharing contract

(PSC) or joint-venture (JV) partners are legally allowed to import hydrocarbons into China (these will be explained in Chapter 4); only NOCs and their partners can construct regional or inter-provincial gas pipelines; only NOCs possess the "mineral right" to produce domestic gas resources, except in the case of some (not all) unconventional gas, where private firms might bid the licences for exploration and production of shale gas without having to establish a JV or a PSC with a NOC.

Although the state is a landlord, it is not a homogenous entity. It is possible that the central government and local governments have overlapping claims to mineral resources. The next chapter will investigate the central-local struggle over mineral rights in the case of coalbed methane (CBM), which have constituted the major hurdle to CBM production for almost two decades. Moreover, the metaphor of "landlord" is not confined to underground resources, but also extends to other territorial rights or power. While the central government decides who can be granted access to resources, drilling and import licences, it is the local (provincial) governments that issue exclusive operation licences to local gas distributing firms on their localised territorial lands.

The process of distributing licenses is opaque and political (as will be discussed in Chapter 5): it constitutes, however, a process which Gonzalez-Vicente (2011, p.402) terms "a process of gradual re-territoriali[s]ation" of the gas network via the regulation of infrastructure for distirubiton and transmission. These discontinous geographies of institutional embeddedness play a particularly important role in the gas industry of China; they largely determine winners and losers at different localities, at different times, and in different sectors. They reward the actors who are so embedded with deep personal, corporate and political relationships with the designers and executors of institutions. These executors have a rich base of knowledge and experience with institutional change and adaptation to the transitions of regulations and requirements, and they punish those who fail to do so. In other words, the "state" largely determines the market access of private and foreign firms, the opportunities and difficulties of gas players, the potential of the "strategic coupling" between China's regional assets and global production networks of gas supply, and the distribution of the value created from gas along the commodity chain, across different firms and provinces.

C. Financier

To encourage gas production and consumption, the state has taken a number of financial measures. For example, while a preferential value-added tax (VAT) of 17 percent had been adopted for oil production, 13 per cent has been adopted for gas production (Zhang 2004). The central government provides a subsidy of RMB0.2/cubic metre for CBM and RMB0.4/cubic metre for shale gas, while local governments provide additional subsidies. The state also helps bankroll large-scale gas projects. Since the energy sector is a "strategic priority" in China and most of China's energy companies are state-owned, the government is urgently seeking to influence the development of the sector through its planning, policies and state budgets (Best & Levina 2012). Through the Export-Import Bank of China (China Exim Bank) and China Development Bank (CDB), the government provides low-cost loans to state firms to carry out projects proposed by either the state or state firms themselves. The policy banks are crucial to the realisation of the "going-out" policy that since the late 1990s encourages SOEs to acquire foreign assets and expand their business overseas. For example, the central goverment launched "loans-for-oil and gas" projects with capital-stricken foreign states after 2008 global financial crisis and the policy banks have played a critical role throughout the process.

Downs (2012) illustrates the importance of these state-owned policy banks to China's oil and gas industry by scrutinizing the case of CDB. In 2009 and 2010, CDB extended lines of credit totaling almost $65 billion to energy companies and government entities in Brazil, Ecuador, Russia, Turkmenistan and Venezuela (Downs 2012, p.1). The loans are secured by revenue earned from the sale of oil at market prices to Chinese NOCs, and in the case of Turkmenistan, the sale of pipelined natural gas at undisclosed prices (my interviews suggest it is about $12 per MMBtu). Downs finds that these energy-backed loans (EBLs) are distinctive to private loans in terms of their large size (up to $20.6 billion), long terms (up to twenty years), the relatively short period of time in which they occurred (less than two years), and their availability at a time when many states were encountering serious cash flow problems to maintain their oil and gas development and virtually no other financial institutions were willing to lend such large amounts of capital for such long terms. Downs also find that CDB, the State Council and China's NOCs worked closely together to frame and execute these EBL transactions; however, one should note that the policy-banks, though wholly state-owned, are not rubber stamps of the state and have their own profit and interest to consider. For example, the EBLs did not only meet the State Council's strategic objectives: they also fulfilled CDB's own agenda of increasing profits, expanding its overseas business portfolio, and protecting its privileged position in China's banking system. Furthermore, the differentiated EBL cases of Russia and Brazil highlight an important fact that the policy banks are not only an executor of central government instruction, but can be at times an initiator and a developer: whereas the State Council and CNPC drove the EBL transaction with Russia, CDB developed the deal with Brazil by itself (Downs 2012).

The recent work of Sanderson & Forsythe (2013) has found at least two advantages of CDB over the World Bank or IMF as a loan provider to resource-rich countries. First, CDB can provide loans at an interest rate competitive with the World Bank and IMF, but compared with the latter two it comes with fewer strings attached, such as having to shore up the country's foreign reserves first. Second, the business mentality of CDB and Western banks is markedly different: when evaluating a potential borrower, CDB looks at the value (be it energy or economic outputs) that its loans and projects will create while "Western institutions are more likely to consider Africa's recent history" (Sanderson & Forsythe 2013, p.113).

However, the "China Inc." argument – that China's government, state-owned banks and NOCs are operating as a coherent entity in a global pursuit of energy – runs counter to actual empirical cases. Gill & Reilly (2007) study China's Africa Policy and find that any coherence to this policy is more a result of internal compromise and negotiation than that of concerted efforts. They find that China's Africa Policy rests heavily on coordination among a complex array of corporations and government bureaucracies. These companies are ranked at city, province, and national administrative levels and are responsible to different bureaucracies of different scales, impeding effective government oversight from the top. Moreover, given the limitations of bureaucratic capacity, geographical distance, and incentives of companies to hide information, government agencies have immense difficulty in accessing timely information sufficient for oversight. Finally, there can be departmental conflicts as the interests of Chinese corporations and their supporting government agencies may conflict with the interests of other Chinese government bureaucratic actors also engaged in Africa.

Domestically, however, the financial regime of China is less favourable to private players. While China's capital market remains heavily reliant on the banking system, which is still relatively underdeveloped and inefficient, banks – and especially the state-owned banks - are more motivated to lend to SOEs than to domestic private firms. A WTO report explained that this is "partly due to the latter's lack of collateral" (World Trade

Organisation 2008, p.110). While some large and powerful domestic private firms (such as China Gas and ENN) can obtain external funding via the capital market, by establishing a listed firm in Hong Kong for example, smaller private firms find it more difficult to enter the sector.

D. Key Player in Bilateral Diplomacy and Supranational Governance

The Chinese state facilitates and sometimes initiates energy diplomacy (either "diplomacy for energy" or "energy for diplomacy") with resource-holding states, states that patrol or are located along a transport corridor (either the sealanes of communication, or existing China's pipelines), and states that have conflicts over energy with China, such as Japan in the case of East China Sea (Kong 2009b, Andrews-Speed & Dannreuther 2011). Diplomacy is implemented through official means, such as summit diplomacy and ministerial diplomacy, maintained through official visits and exchanges, supported by the Ministry of Foreign Affairs (MAF) and the Ministry of Commerce (MOC) and sometimes sweetened by the financial packages from the policy banks mentioned above in the forms of "loans-for-oil and gas" and "projects-for-oil and gas". Erica Downs found that "energy projects top the agenda of China's diplomatic missions to hydrocarbon rich countries" (Downs 2004a, p.68), and Chinese diplomats played an important role in CNPC's successful bids for oil projects in Venezuela, Sudan, and Kazakhstan. At times the state even provides official narratives to highlight its historical presence in a region in order to justify its energy diplomacy, ease international worries about its intentions, and amass "soft power". For example, the Chinese government has been tapping into the history of the Muslim admiral Zheng He in the Ming Dynasty and his official visits to East Africa some 600 years ago. In a speech delivered in South Africa in 2007, President Hu Jintao claimed that Zheng He's naval fleet "brought to the African people a message of peace and goodwill not swords, guns, plunder or slavery" and used Zheng He to "fashion a diplomacy that bestows legitimacy on China's overseas aspirations" (Power et al. 2012, p.59).

The state is also the major player and participant in a variety of supra-national governance groups that affect the development of the domestic natural gas industry in various ways. China became a member of the WTO in 2001 and, as a consequence, had an obligation to open up its downstream markets for oil products, such as petrol stations and refineries, to international companies after 2004. China's WTO membership did not have a direct impact on the structure of its natural gas industry (IOC participation remains confined to offshore or unconventional gas reservoirs in partnership with Chinese NOCs), but it has had some significant indirect influences. A fear of potential cut-throat competition in a “strategic” sector led the Chinese government to strengthen the power of NOCs through a process of restructuring, creating vertically integrated firms before becoming a WTO member. The springing up of IOCs in China’s downstream oil sector has motivated these companies to establish closer networks with the government and NOCs by working with them in other areas such as gas production. My interview with Shell China confirms this argument and will be discussed in the Chapter 4.

Another example of a supra-national governance group that affects China’s sub-national gas industry is the Clean Development Mechanism (CDM). One of the flexibility mechanisms defined in the Kyoto Protocol, the CDM allows non-Annex 1 countries, including China, to generate Certified Emission Reduction (CER) units for sale to Annex 1 countries: the principle of the CDM is that it allows industrialised countries to invest in emission reduction where it is cheapest globally. Up until 2012, China had established 3,992 CDM projects that accounted for 55.6 percent of total projects (or 71 percent of CER units) in Asia Pacific. Of these 102 were coalbed methane (CBM) projects (Programme 2013).

A more visible example would be the Shanghai Cooperation Organisation (SCO). Originally established as Shanghai Five in 1996 by China, Kazakhstan, Kyrgyzstan, Russia and Tajikistan, the organisation was renamed as SCO in 2001 when Uzbekistan was included (note that the Turkmenistan, a large gas-exporting country, is not a SCO member). Originally a military and counter-terrorism inter-governmental organisation led by China and Russia, SCO has become a more comprehensive political-economic platform. SCO is not an internally coherent entity, as it is formed by countries with differing interests (including significant differences in the field of energy): the formation of an effective SCO energy club, an idea raised by Russia in 2006, therefore remains unlikely. Nonetheless SCO provides an important platform for diplomatic negotiation and legal settlement for states and firms involved in, for example, the Central Asia-China Gas Pipeline project, among others (Paik 2012).

So far, Chinese political leaders are more interested in participating in bilateral or regional energy governance regimes, rather than joining multi-lateral ones such as International Energy Agency (IEA), which has expressed interest in changing the OECD membership requirement to include China and other non-OECD energy entities (Kong 2011). My interview with a China energy governance expert (Interview 1), who has frequent contacts with Chinese diplomats and military leaders, finds that Chinese leaders almost subconsciously equate international cooperation with global governance, and by "international cooperation" they mean the sum of bilateral or regional cooperations. The links between China's natural gas production network and global energy governance networks (e.g. IEA, Energy Charter Treaty and APEC) will not be further discussed, but the above discussion serves to recognise the "trans-local" nature of gas production network, meaning that decision-making of a local firm could still be significantly affected by some supranational institutional arrangements engaged by the state.

E. National Champion

The state has a corporate face too, as it creates and continuously oversees the SOEs that run energy businesses. Internationally, NOCs now control approximately 90 percent of the world's oil and gas reserves and 75 percent of production (Tordo et al. 2011 p.xi). Inkpen & Moffett (2011) categorised NOCs into two types - resource-rich NOCs, and resource-poor NOCs – and assert that while the function of most NOCs in resource-rich countries is to control and manage national oil and gas resources, NOCs in resource-poor countries like India and China exist to manage the country's energy security needs. This dichotomy might be a useful point of entry but it risks oversimplification or over-generalisation. Studying the case studies of NOCs across the world, Tordo et al. (2011) finds that NOCs differ on a number of very important variables, including the level of competition in the market in which they operate, their business profile along the sector value chain, and their degree of commercial orientation and internationalisation. At the same time, they also find that most NOCs share at least some core features: they are usually tied to the "national purpose" and serve political and social goals other than maximising the firm's profits. For example, Chinese NOCs are not allowed to adjust wellhead gas prices despite the presence of more expensive gas imports, resulting in losses. The CNPC reported a loss of 14.45 billion RMB from its natural gas imports in 2012, up more than 40 percent year-on-year (Song 2013).

NOCs can be involved directly as producers or gatekeepers for exploitation by private and foreign energy firms, and in China, NOCs serves as both. Although energy security was the key rationale for the birth of Chinese NOCs, they are also active shapers of Chinese energy security narratives. Downs (2004a) discovered that NOCs are the key drivers of China's "supply-side" energy security policies and discourses, including the questionable narrative that the "going-out" strategy of NOCs in acquiring overseas equity oil and gas axiomatically contributes to China's national energy security. In recent years, researchers like Downs (2004a), Andrews-Speed & Dannreuther (2011), Chen (2011) and Leung (2011) explicitly assert that the overseas activities of Chinese NOCs are, while often under the banner of "energy security", primarily commercially-driven. Inkpen & Moffett (2011) rightly point out that Chinese NOCs, unlike the resource-rich NOCs, are becoming increasingly similar to IOCs in that they must find overseas oil and gas reserves to replace their declining domestic assets.

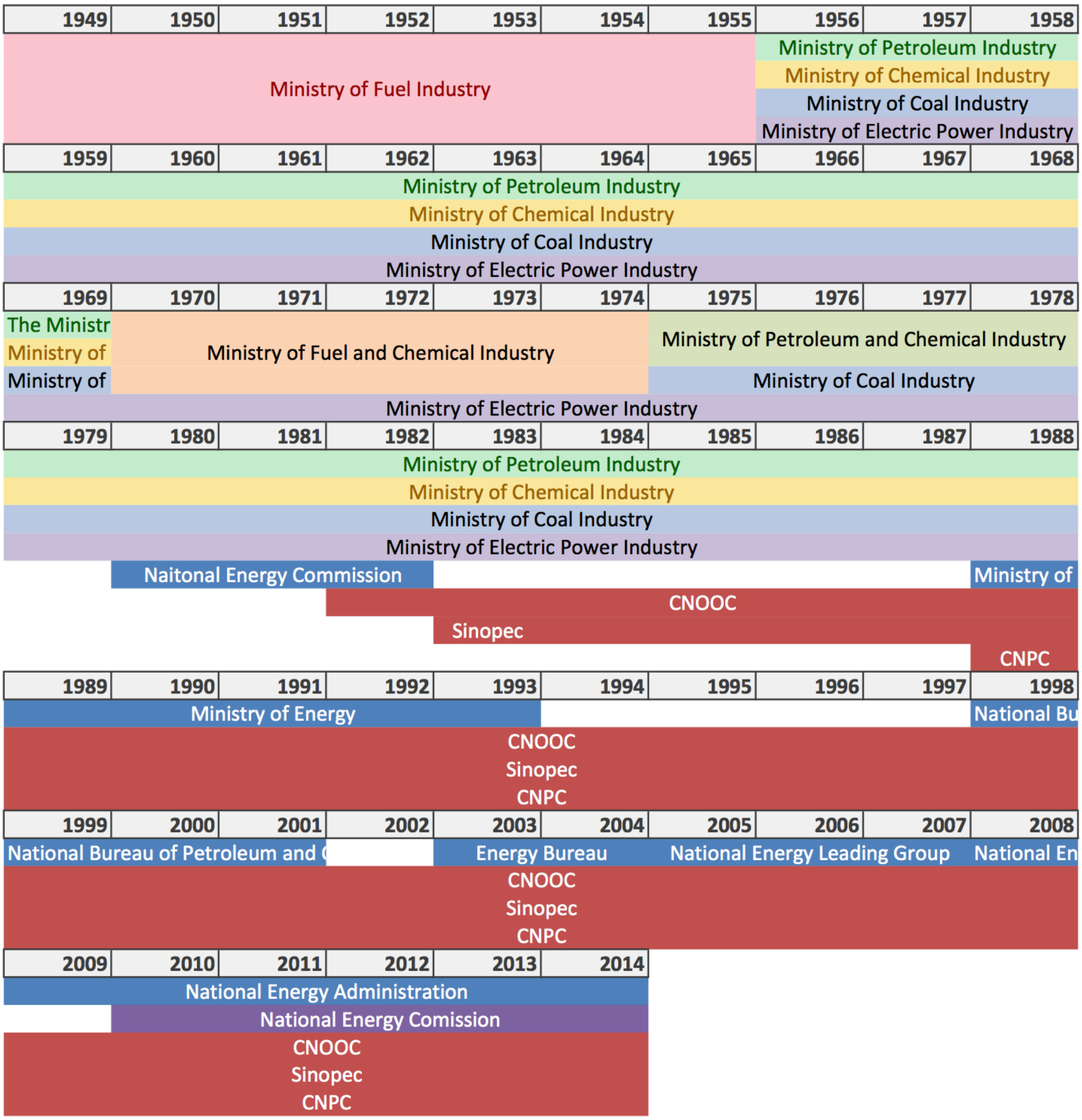
In China, energy SOEs can be owned by either the central government, such as the NOCs, e.g. CNPC/PetroChina, or local governments, such as those downstream gas distributing firms (e.g. Beijing Gas). As with oil, the gas sector in China is predominated by the biggest NOCs, including CNPC, Sinopec and CNOOC. CNPC is the single largest NOC that accounts for some 70 percent of China's total gas outputs and controls the vast majority of gas distribution pipelines domestic gas pipelines (via its listed arm, Kunlun Energy). It is becoming even more vertically integrated as a gas firm, as its recently established non-listed gas distributing firm, Kunlun Gas, is actively competing with other downstream gas players in a way my informant from a key gas distributer would call "ferocious" (Interview 2). Kunlun Gas is part of CNPC, the country's single largest gas supplier, and thus enjoys the largest degree of supply security of gas. My interview with one of the founders of Kunlun Gas finds that Kunlun Gas, though only established in 2008, will likely become China's largest gas distributor by 2020, meaning that the monopoly of CNPC in the gas sector will be further reinforced at the expense of other private gas distributers (e.g. China Gas) and local government gas suppliers (e.g. Beijing Gas). Chinese entrepreneurs have a phrase to describe this unsettling development in recent years: "*guojin mintui*", or "the state advances while the private sector retreats" (The Economist 2012a).

The other two NOCs are less vertically integrated than CNPC, but they equally have exclusive accesses to domestic gas reserves, the kind of privileged right other firms do not enjoy. Sinopec, for example, operates the Puguang gas field in Sichuan, one of the country's most promising upstream assets. CNOOC has led the materialisation of China's first three LNG receiving terminals in Guangdong, Fujian and Shanghai, and is responsible for much of China's offshore gas production. Since the NOCs are the only corporate managers of China's domestic gas resources, IOCs and other private gas firms must cooperate with them, typically through signing production-sharing contracts (PSC) (U.S. Energy Information Administration 2013). We will discuss below how NOCs have become so powerful while the central energy authority has sometimes lost its power to rein them in.

3.3. Decentralisation and Recentralisation: Institutional Transitions in China's Energy Governance at the Central Level

The "state" dominates China's gas network but it is far from a unified entity. China is still a communist state, and thus it is quite common for outside observers to jump to the conclusion that it is still a monolithic entity with a Leninist hierarchy. However, since the economic reforms and open door policy in the late 1970s, the matrix of power in China has been becoming more complex and fragmented. Political scientists have deemed the Chinese system a "negotiated state" or a "consultative authoritarian regime", where "space for autonomy, loopholes for bargaining, and hopes for democratisation" have been created, allowing factionalism, localism and departmentalism to thrive (Xia 2006). As early as in the 1980s, Lieberthal & Oksenberg (1988) already developed a model of "authoritarian fragmentationism" to conceptualise the decentralising dynamics of the centralised regime of China and "the increasing pluralisation of the policy-making process", as "policy made at the centre becomes increasingly malleable to the parochial organisational and political goals of various vertical agencies and spatial regions charged with enforcing that policy" (Mertha 2009, p.996). The model has inspired contemporary energy scholars, including Erica Downs, Philip Andrews-speed, and Kong Bo, to make sense of China's fragmented energy governance, often by analyzsing the development and interaction of China's energy institutions. Today, heated negotiation, bargaining and squabbles between different departments, interest groups or "cliques" (e.g. the "oil clique") are pronounced and widespread, often resulting in lengthy decision-making and ineffective governance. Evidences suggest that the central government is increasingly challenged by, or dependent on, local governments and NOCs. This section traces back the historical development of China's institutional energy governance. It breaks this history into four phrases, which can be characterised as a back-and-forth shifting in the balance of power between the central government and the subordinate entities of local governments and NOCs (Figure 3.1).

Figure 3.1 Transitions in China's Energy Institutions, 1949-2014



Source: The Author

3.3.1. Phase 1 - Central Planning (1949-1977)

The People's Republic of China was founded in 1949. As a newly established communist regime, the government strictly adopted the Soviet Union's administrative structure and centralised economic planning system. During the Cold War, the central government completely controlled the country's limited strategic resources ranging from iron and steel to energy. The Ministry of Fuel Industry was established in 1949 as the only ministry responsible for all energy production. However, after the beginning of the Korean War, the Ministry of Fuel Industry was judged incapable of producing energy as quickly as needed. Therefore in 1955 it was replaced by four new energy ministries, namely the Ministry of Petroleum Industry, the Ministry of Coal Industry, the Ministry of Chemical Industry and the Ministry of Electric Power Industry. Ironically, these four ministries became too decentralised during the Cultural Revolution, and the State Council decided to merge these ministries (except the Ministry of Electric Power Industry) into the Ministry of Fuel and Chemical Industry in 1970. However, such efforts at recentralisation failed because decentralised political power had already taken root and the Ministry of Fuel and Chemical Industry did not have any real power over the energy sector. Ironically again, it was redivided into the Ministry of Coal Industry, and the Ministry of Petroleum and Chemical Industry in 1975. The latter was further divided into the Ministry of Petroleum Industry and the Ministry of Chemical industry in 1978 (Bao & Houlden 2013). Therefore, even within the same central planning era, there was not always a centralised energy overseer and the transition was never a linear process.

3.3.2. Phase 2 - Transition to a Market System (1978-1997)

The beginning of economic reforms in 1978 came with the introduction of a more market-based institutional system. This phase also saw multiple processes of decentralisation and recentralisation, but overall they involved moving towards more market-based management. To take back the power over SOEs from the local and decentralised departments during the Cultural Revolution, the central government established the National Energy Commission in 1980, which was another umbrella entity responsible for the coordination of overall energy development in China, as well as the supervision of energy-related ministries. But it was dissolved quickly in 1982 because it failed to stimulate oil production, which was in shortage. Instead, the central government decided to create NOCs to tackle the problem. It established CNOOC in 1982 to accelerate offshore oil and gas development through international cooperation; Sinopec in 1983 by merging the country's 39 major petrochemical and refining enterprises, which previously belonged to the Ministry of Petroleum Industry, the Ministry of Chemical Industry and the Ministry of Textile Industry; and CNPC in 1988 by restructuring the Ministry of Petroleum Industry. The establishment of the Ministry of Energy in 1988 was another attempt of the central government to recentralise power, but it was abolished in 1993 because it had overlapping authority with State Planning Commission (i.e. the predecessor of the current NDRC) (Bao & Houlden 2013). It was also because then Premier Li Peng wanted to lift regulations and make the NOCs improve their exploration and production efficiency in order to increase China's energy security by exposing them to the market forces (Li 2011).

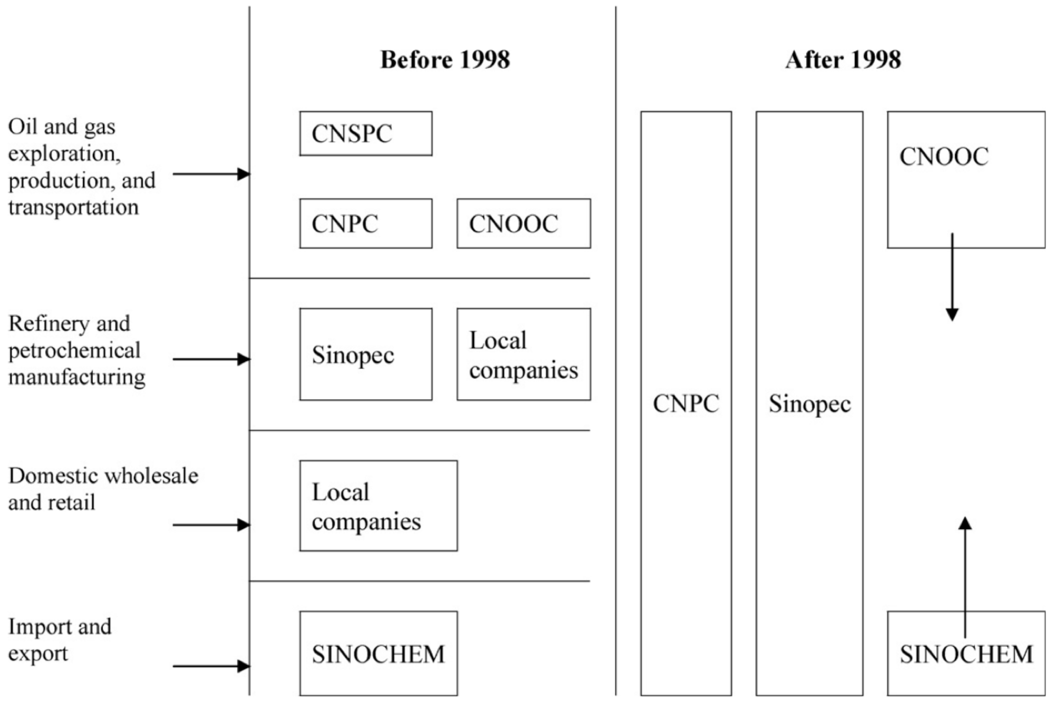
3.3.3. Phase 3 - Centralisation and Commercialisation of NOCs (1998-present)

As mentioned, all Chinese NOCs were born in the 1980s, but it does not mean there had not been government oil and gas production units before. These production units, under the socialist model of danwei, are self-contained. Since many of them are located in remote areas, the productions units needed to provide labor with everything they needed, including a welfare system, agricultural production, crop processing, housing construction, a heating system, hotels and restaurants. Zhang (2004) commented that they were "run like a little country". Gradually, these production units had developed a strong sense of their own identity before they were administratively put under the corporate boundaries of NOCs. These administratively established NOCs were "facades that extended the influence of self-preserving bureaucratic players" and showed little capacity in coordinating their subsidiaries (Lin 2006). At best, they had nominal supervisory status over firm-level decisions of individual oilfields and refineries, which tended to follow local allegiances. The production and financial targets of the NOCs were still set by the state, in the form of the FYP.

The self-contained production units had struggled for corporate and business autonomy with the NOC headquarters in the 1980s and 1990s. Zhang (2004) finds that some production units, such as Daqing (a prefecture-level city in the west of Heilongjiang province), were very politically and economically strong. The discovery and production of Daqing's oil in the 1960s dramatically transformed China into a energy self-sufficient country at a time when the West placed an embargo on China after the outbreak of Korean War, and the Soviet Union no longer supplied oil to China (Leung 2011). The sheer success of Daqing was selected by Mao Zedong as the model for the state-owned enterprises in China and was regarded as a "flagship" among New China's industrial sectors (Zhang 2004). Daqing also contains the largest oil reserves, accounting for 55.6 percent of CNPC's total proven reserves (Zhang 2004) and has been the main production centre for decades. Understandably, people working there are immensely proud of its history and being 'Daqing people' (*Daqing ren*). In 1988, Daqing proposed that they should be allowed to operate independently following international practices. They even offered to hand over to the government an additional 15 billion yuan, equivalent to the amount of profits handed over by the whole of Sinopec every year. In 1992, they proposed that they should be listed on the domestic or international stock market. Both proposals were turned down by CNPC Headquarters. Daqing's battle for independence reached its climax in 1996 when, led by Director Ding Guiming, Daqing explicitly expressed its wish to become an integrated multinational company and started its own internal restructuring programme. At the same time, CNPC constantly stressed that oil is a strategic commodity and the oil industry must be under direct state control, with CNPC the representative of the state. CNPC headquarters sent a blunt message to Ding Guiming that he would be treated as a criminal if he led Daqing to independence. In the end, Ding was moved to CNPC headquarters and later sent to work for the State Council (Zhang 2004).

In March 1998 the Chinese government started a major SOE reform programme and aimed to create two vertically integrated NOCs, the new CNPC and the new Sinopec (Figure 3.2). Prior to China's entry to WTO in 2001, the central government sought to establish national champions in the oil and gas sector that were internationally competitive. Against the backdrop of depressed international oil prices and mergers and acquisitions among IOCs in the late 1990s, premier Zhu Rongji restructured the NOCs into vertically integrated firms that run both upstream and downstream businesses in assigned geographical areas, by reallocating the assets of the NOCs. As a result, the functional division is replaced by territorial one. Nearly all state-owned oil and gas fields, refineries, and petrochemical plants have been incorporated into two onshore vertically integrated firms, namely CNPC and Sinopec, roughly demarcated along the territorial boundary of the Yellow River. Under the scheme, Sinopec transferred nineteen petrochemical enterprises to CNPC. CNPC transferred to Sinopec twelve enterprises including eleven enterprises engaged in oil exploration and production, and Zhongyuan Petrochemical. Refineries and chemical plants formerly under the Ministry of Chemical Industry were transferred to either Sinopec or CNPC depending on the location of these refineries. CNPC and Sinopec were allowed to expand their marketing activities, especially retail business, into each other's territory. Moreover, the two companies were empowered by the State Council to make their own investment decisions, including forming joint ventures with foreign companies and raising funds to finance growth (Zhang 2004). My informant from CNPC stated that the inter-NOC competition was so intense at that time that CNPC and Sinopec even got involved with weapons in Henan in 2003. Lin (2006) regarded this period of reform as a "disembedding" process that "disrupt[s] preexisting social norms and exchange relations of the planned economy" and, simultaneously, a "re-embedding" process that installs a "new system of social relations supportive of market norms and principles" (Lin 2006, p.59). The NOC reform between 1997 and 2002 was seen to be in the footsteps of East Asian and European dirigiste economies in fostering "commanding heights" or "national champions".

Figure 3.2 China's NOC Structure before and after 1998



Source: Chen (2009, p.253)

Shaofeng Chen rightly argues that "[t]he 1998 restructuring has resulted in today's oligarchic monopoly structure" (Chen 2009). The reforms created vertically integrated NOCs, which now have obtained centralised control, unified corporate agendas and thus a much stronger influence on China's energy governance. In the early 2000s, the NOCs listed their core assets. In 2000, CNPC separated most of its best assets, including 480,000 of its original 1.54 million employees, to a subsidiary called PetroChina, and carried out an initial public offering (IPO) of around a 10 per cent interest on the New York and Hong Kong stock exchanges. The remaining 90 per cent was still owned by CNPC and the top officials of PetroChina are virtually identical to those of CNPC. Also in 2000, Sinopec Group transferred its high quality assets, including 400,000 out of the company's original 1.12 million employees, to a subsidiary called China Petroleum and Petrochemical Corporation (Sinopec), and carried out an IPO of around a 10 per cent interest on the New York and Hong Kong stock exchanges, with the remaining 90 per cent owned by its parent firm, Sinopec Group. In 2001, CNOOC held an IPO of a 20 per cent stake of its subsidiary, CNOOC, Ltd. Interestingly, since CNOOC was formed to manage China's energy relations with foreign firms interested in exploring and developing Chinese offshore oil and gas, it is used to working closely with foreign firms. In the IPO of CNOOC Ltd., Shell bought 20 per cent of the shares as part of a strategic alliance with the parent company, CNOOC (Downs 2004a).

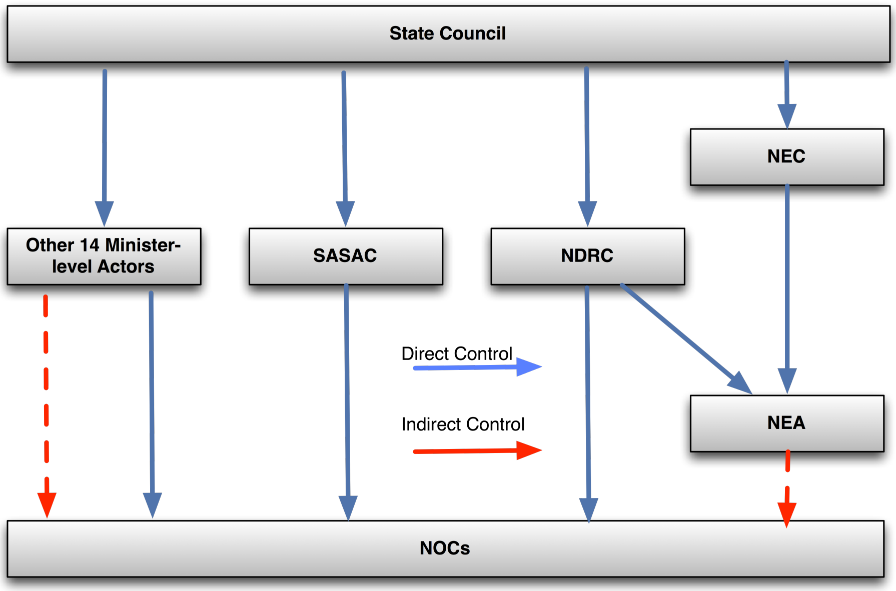
The ownership complexity of Chinese NOCs sometimes confuses overseas observers; for example, Inkpen & Moffett (2011) mistakenly assume that PetroChina was founded in 1988 and now has only 500,000 employees, while PetroChina is only a partially privatised subsidiary of CNPC with more than a million workers. Trying to clarify the relationship between CNPC and PetroChina in order to understand that between a NOC and its listed company, Zhang (2004) had several findings. First, there is a non-competition agreement between CNPC and PetroChina: so long as CNPC controls no less than 30 percent of PetroChina's shares, CNPC will not engage in any businesses within or outside China that directly or indirectly competes with businesses in which PetroChina is involved. When CNPC find business opportunities that are in competition with PetroChina, CNPC must inform PetroChina of these business opportunities immediately. Second, CNPC grants PetroChina the option to purchase at any time all of CNPC's overseas assets. CNPC retains the non-core assets and businesses, such as oilfield service, and these services could be of important to PetroChina's core businesses. If the services are not available from other independent companies, PetroChina will pay CNPC the actual cost of the service. Third, since CNPC is the controlling shareholder, it draws its principal income from PetroChina's dividend payment (which was as much as 53 percent of PetroChina's net profit in 2000) to maintain the often loss-making non-core business and social functions (such as education, medical care, social security, retired employee administration etc.).

3.3.4. Phase 4 - Attempts to Re-centralise Energy Authority (2003-present)

Since the abolishment of the Ministry of Energy in 1993 by then Premier Li Peng, there had not been a central energy overseer in China. Vice-Premier (and Premier from 1998 to 2003) Zhu Rongji deliberately enhanced the financial and administrative autonomy of China's NOCs to make them more efficient in preparation for the listing of their subsidiaries on international stock exchanges (Downs 2006). A new generation of central leadership, led by President Hu Jintao and Premier Wen Jiabao, emerged in 2003. Recognising the problem, there have been numerous attempts to re-establish an energy governance institution at the central government level. In 2003, the NDRC set up the Energy Bureau. However, the capacity of the Energy Bureau was very limited due to lack of resources and political influence. Recogizing the inefficacy of governance, the National People's Congress, the highest state body and the unicameral legislative house, established the the National Energy Leading Group (ELG) and its administrative body, the State Energy Office (SEO), with an objective of reducing the influence of energy firms, especially NOCs (Li 2011). The ELG operated under the State Council led by Premier Wen Jiabao, and thus was able to intervene in the energy sector to solve particularly prominent problems as they arose. It was, however, not involved in the day-to-day operations of the energy sector. The SEO had the bureaucratic rank of a vice-ministry, below that of the NDRC and NOCs and thus was not particularly powerful.

In 2008, the ELG and SEO were replaced by the National Energy Commission (NEC) and the National Energy Administration (NEA), respectively, forming the central government structure today. Given the lack of an Energy Law to regulate responsibilities (my informants from NEA hinted that the NOCs were taking efforts to block the passage of the Energy Law to prevent any redistribution of power), China's energy governance at the national level suffers the problem of "too many cooks in the kitchen". For example, in 2012 the NEA needed to work with NDRC, the State Asset Supervisory and Administration Commission (SASAS) and 14 other ministry-level departments under the State Council, which results in incoherent, disjointed and lengthy policy-making (Figure 3.3). The energy authority of the NDRC itself is dispersed across at least among four other departments in addition to the NEA – the Department of Pricing, the Department of Basic Industries, the Department of High-Tech Industry, the Department of Resource Conservation and Environmental Protection (Kong 2011).

Figure 3.3 China's Energy Governance at the Central Level since 2008



Source: The Author

Realising the problem of China's weak energy governance structure, the central government established the NEC in 2010. The NEC, previously led by Premier Wen Jiabao, is now led by current Premier Li Keqian. It is composed of heads of 21 other central bureaucracies with strong political clout, but it is an ad hoc body that meets irregularly. It is de facto a consultative body with no budget, staff or residency (Kong 2011). But this does not imply that the decision-making process is always lengthy and unproductive. If the plans or projects can create values for most stakeholders to capture, the decision-making process can be strikingly fast. Conversely if proposed ideas do not create value but merely reshuffle existing interests, passing them will become more difficult. This explains why it took China seventeen years to pass the introduction of a fuel tax but only two years to confirm the construction of the gigantic West-East Gas Pipelines (Kong 2009a).

3.4. Relational Landscape: Central and Local Governments and NOCs

3.4.1. "The Emperor is Far Away": Central-Local Government Relations

There is an old Chinese proverb, "the mountains are high and the emperor is far away". Localism, feudalism and regionalism pervade the history of China. Amid the disappearance of a powerful and centralised energy authority, the local (provincial) governments and NOCs are becoming progressively powerful, in terms of politics, finance and human resources. Oi (1992) argued that the economic reforms, especially that of "decollectivisation" in 1984, resulted in a significant increase in the economic power of the local officials thanks to their ability to assert control over assets that were previously collectively owned. The reforms led to property rights of local officials, who in turn are motivated to pursue local development. Oi coined the term "local state corporatism" and regarded local officials as directors, making decisions about management, credit, resource allocation and investment. Although Oi's argument that local governments are the principal agents of China's economic development might have downplayed the role of the central government, he correctly acknowledged that the central government is no longer a centralised regime. The 1994 tax reform provided further incentives for local governments to look for ways to maximise their own financial benefits. This national fiscal restructuring required local officials to be responsible for their balance sheet: it hardened budget constraints but allowed officials to attain local taxes (Whiting 2001). Under this new regime, local governments are primarily accountable for the economic performance of their regions, which constitutes the chief measurement of local official's performance and a critical criterion for official promotion. Local governments, therefore, are motivated to overshoot the centrally set target if a particular policy creates value for the locality and to underperform if the policy requires local sacrifices. For example, when the NEA planned to create major 20 coal production bases by 2015 in order to better centralise and coordinate coal supply, the targeted coal-rich provinces had already established 24 bases by 2010 with production capacity much higher than the NEA target. When the 11th FYP (2001-05) launched a nationwide campaign to reduce national energy intensity (in terms of the amount of energy needed to generate a given amount of GDP) by 20 percent, some provinces continued to allow the energy inefficient production capacities to operate and expand, and in some cases, they even exaggerated their reductions of energy intensity (Kong 2011). According to my interview with an NEA staff person, local governments either understate their actual energy consumption or overstate their GDP to exaggerate their energy intensity cut. The increased economic and political autonomy has had a great impact on China's gas industry, especially the downstream city-gas supplies. Since it is provincial governments, instead of the central government, that issues exclusive business licences to downstream gas distributing companies, to obtain the dividend from the development of gas industry and gas sales local governments often establish their own firms (i.e. local SOE) or demand that bidding firms form JVs or stock-sharing partnerships.

Given the increased political and economic autonomy of local governments, the perceived threats presented by local protectionism or federalism, whether justified or not, led the central government to attempt to re-centralise certain offices within a handful of bureaucracies in 1998, shifting the chain of command from a overly localised regime to a more vertical one. Studying the centre-local relations of China, Mertha (2005) proposed the notion of "soft centralisation" to describe these new power dynamics. It was "soft" because it was not a complete centralisation; instead bureaucracies were centralised from the township/county to the provincial level, while the provincial governments remain decentralised from the centre. Mertha (2005) went on to argue that the prime beneficiaries of this shift to more centralised management are the provincial governments and not Beijing, as the institutional mechanisms of personnel and budgetary resource allocations are now more concentrated at the provincial level. By transferring power and resources from township/country governments to the newly centralised bureaucracies (the provincial governments), "it has also contributed to a situation in which newly strengthened provinces may play a key role in the emergence of a sort of perverse federalism" (Mertha 2005, p.792). The 1998 government reform has thus been a further reinforcement of the bargaining power and autonomy of provincial governments.

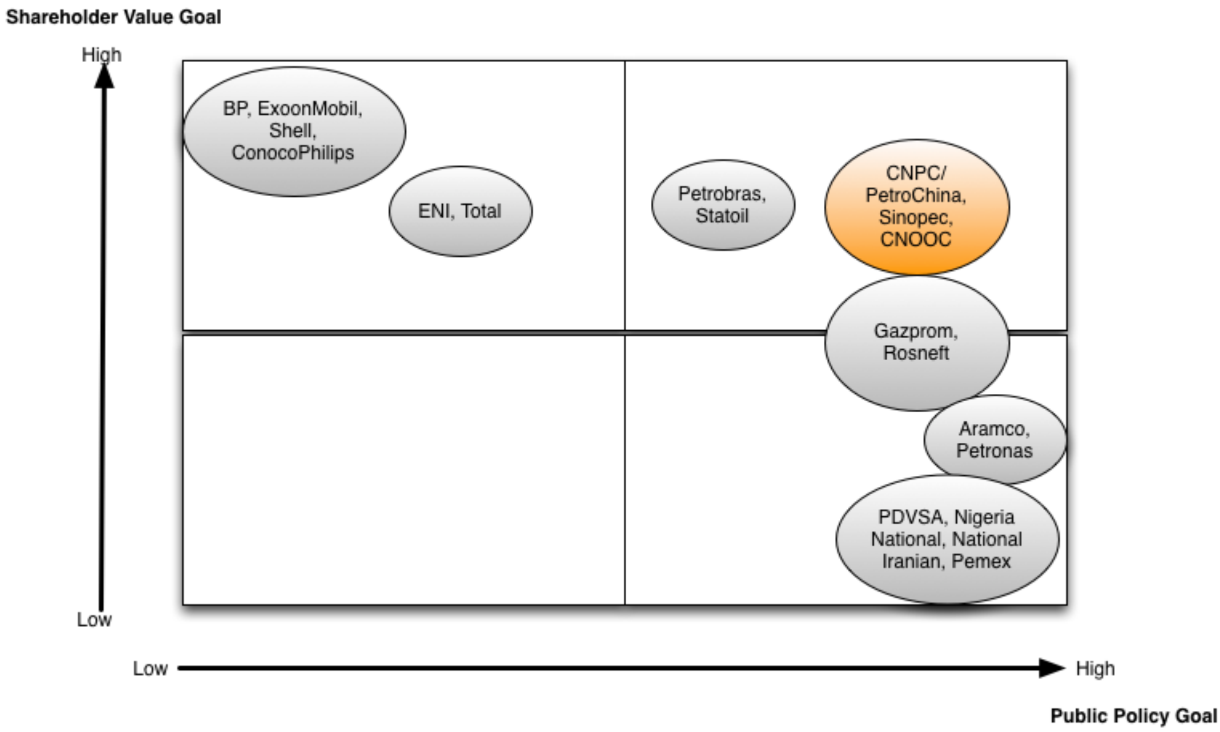
3.4.2. NOCs' Bounded Free Will: Central Government-NOC Relations

The idea that Chinese NOCs are loyal and obedient to the commands of the central government still pervades Western world politics and business. A commentary titled "China Inc." published on Bloomberg in 2010, for example, bluntly stated that "Communist leaders have ordered state-owned companies to buy up private rivals, causing some foreign investors and trade groups to cry foul" (Forsythe 2010). When CNOOC Ltd, the listed arm of CNOOC, attempted to buy the California-based energy firm Unocal Corp. in 2005, it faced enormous "resistance from politicians in Washington who said such a deal could threaten U.S. national security and violate the rules of fair trade" as US politicians were unease over the fact the Chinese government owned 70 percent of CNOOC Ltd (Ben White 2005).

Erica Downs (2007) was probably among the first group of specialists who have tried to systematically debunk the "China Inc." argument in relation to energy. While it is true that the central government has been supportive of NOC overseas expansion, it is NOCs' own profit-seeking mentality that has driven their overseas activities, and it is also their own knowledge and judgement that strategise the implementation, including deciding on where to invest. NOCs sometimes even ignore the “guidance” of the central government. For example, although NDRC in 2007 excluded Sudan from a list of countries in which NOCs were encouraged to invest (in order to avoid further diplomatic pressure approaching the 2008 Olympics), CNPC/PetroChina acquired even more assets.

Figure 3.4 seeks to position China’s NOCs as a group compared with other NOCs and IOCs. Strictly speaking CNOOC is even more internationalised and corporatised than CNPC and Sinopec as it was set up by the government for cooperation with IOCs over offshore E&P from the beginning. Like other NOCs, China’s NOCs are entrusted with meeting public policy interests, such as selling oil and gas at lower prices to farmers and chemical fertiliser manufacturers or building strategic petroleum reserves (SPR) for national energy security. China’s NOCs, however, increasingly behave like private, multinational enterprises, and need to meet shareholders’ expectations especially after they listed their core assets. For example, Downs (2006) found that the motives for NOCs’ overseas expansion are largely commercially driven. First, NOC overseas expansion is for reserve replacement and diversification. Like the IOCs, NOCs need to establish larger and geographically more widespread reserves to ensure its long-term survival and growth. Since China’s domestic reserves of oil have reached a plateau, Chinese NOCs need to look elsewhere if they want to stay in and expand business. Second, NOCs’ overseas activities are profit-oriented. The exploration and production sector is historically the most profitable part of the oil and gas business. Although some question the actual motive of them settling for lower rates of return than IOCs normally would, Downs explains that it is because NOCs face less pressure from shareholders as the major shareholder of NOCs is the Chinese government, so basic profitability is already acceptable to them. Overseas oil and gas outputs are also free of Chinese pricing regulation, so Chinese NOCs can make profits by selling the oil and gas in the local market. Albeit the rhetoric that the “energy security” agenda motivates NOCs to invest overseas, the truth is that the equity oil and gas of Chinese NOCs are seldom shipped back to China (Leung 2011). Finally, it is to increase their international competitiveness. To make NOCs internationally competitive, the leaders of NOCs need to make their firm compete internationally. Mark Qiu, former chief financial officer (CFO) of CNOOC Ltd, colourfuly stated, “we have to learn to play world club; you can’t just play domestic league” (Downs 2006). Chen (2008) similarly argues that China’s energy diplomacy has been driven by the NOCs’ strong commercial motives to expand business abroad and their management’s personal incentive, not just the government’s strategic concerns. At the same time, it should noted that China’s internationalised NOCs are not IOCs, and their overseas expansion are not entirely business-oriented, but for gaining political and economic influence. Acquiring foreign oil assets helps Chinese NOCs gain influence with key energy officials as well as access to capital from state-owned policy banks. The more assets a company acquires, the more likely it is to gain support for subsequent acquisitions. This holds particularly true for CNOOC, which does not have as much political clout as CNPC and Sinopec.

Figure 3.4 The Strategic Goals of IOCs and NOCs



Source: Modified from Inkpen & Moffett (2011)

Given the decentralisation of China's energy decision-making body at the central level and the rising power of NOCs, NOCs now play an important role in shaping the official discourses and policies on energy. The influence of NOCs in China's energy governance is penetrating and widespread, to the extent that Kong (2009b) coined the term "co-governance" of government and NOCs to capture the dynamics. The significance of NOC influence vis-a-vis central government can be observed in several ways. First, as noted, whereas the decision-making, interests and agenda of NOCs have become coherent and centralised since 1998, those of central government are fragmented, departmentalised and incoherent. It is easier for NOCs to lobby certain members of the latter. In fact, the central energy authority now often needs NOCs to support them because it is seriously understaffed. Downs (2008) reported that NEA, which is supposed to govern China's entire energy sector and approve all major energy investments in China, has only 112 full-time staff. The staff size is very much smaller than that of the US Department of Energy, which has about 4,000 employees dedicated to energy matters. Downs speculates that the State Commission Office for Public Sector Reform (the government body that determines the functions, internal structure, and staff quotas for government institutions) has probably resisted NEA's calls for more personnel for the fear that other government bodies would similarly press for more manpower and limit the State Council's attempts to streamline the bureaucracy. My interview with one of the NEA full-time staff in June 2013 found that the NEA now have only about 120 full-time members (Interview 3). Facing a lack of human resources but not allowed to hire more official members, NEA has to "borrow" energy experts from energy firms regularly, and one can easily assume that many if not most of them are from NOCs, which have more than a million employees, have their own research units and have recruited most of China's oil and gas outstanding specialists.

Second, the personal networks embeddded in NOCs often undercut the authority of the NEA. As a vice-ministerial body, NEA lacks the authority to effectively coordinate the interests of ministries, commissions, and many state-owned energy companies. Interviewing a couple informants from CNPC, I found two very different versions of the story explaining how CNPC and Sinopec are politcally superior to NEA. The first version is that both CNPC and Sinopec were created out of the Ministries of Fuel Industry and of Chemical Industry in the 1980s, and they inherited the ministry-level ranks. In this case, these NOCs are bureaucratically superior to NEA, which holds only a vice-ministerial rank (Interview 4). The second is that NOCs are not government departments and thus cannot inherit any bureaucratic rank, but the heads of CNPC and Sinopec are often former ministry-level officers (Interview 5). In this case, the heads can get around the NEA and lobby the key members in NDRC, State Council or even Politburo. Li (2013) talks about the ubiquitous political influence and ambitions of the "oil clique", which is a group of politicians who achieved political status through careers in the oil industry. For example, Jiang Jiemin, until recently was head of the State-Owned Assets Supervision and Administration Commission (SASAC) that supervises all SOEs including NOCs, and before that he was President of CNPC/PetroChina. Zhou Yongkang, who recently stepped down from his positions on the State Council and on the Standing Committee of the Politburo, was General Manager of CNPC in the mid-1990s. Although how coherent and institutionalised the "oil clique" is remains unclear, it is reasonable to assume that the heads of NOCs, appointed by the Central Committee of the Chinese Communist Party (CCP), can have more have direct access (or *guanxi*) to top Chinese leaders, especially those used to work for, and are more sympathetic to, NOCs without the need to go through government institutions.

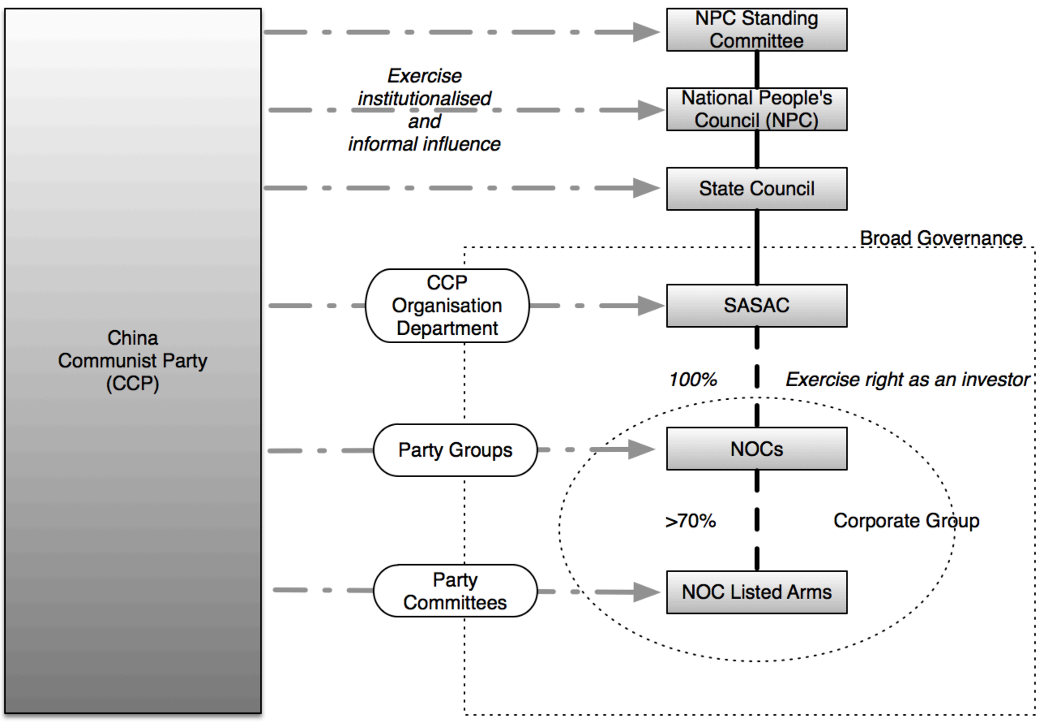
In recent years, it seems to many observers that the NOCs, suffering financial losses from oil refining and, more recently, from importing natural gas, have the habit of playing political games to "subtly" press for pricing reforms. These games include constraining refinery output and exporting the output when their losses from selling to the domestic market grow too high (Andrews-Speed 2013). Since May 2013, for the first time, CNPC, which controls roughly 70% of the nation's gas supply, has begun rationing supplies in northern regions including the provinces of Shandong and Hebei by 26%. Even before the gas cut, CNPC's supply was already not enough to meet market demand. Since residential gas users have their supply protected by law, local suppliers have no choice but to cut supplies to industrial and business clients, even though these bulk buyers are the major profit generators to local distributing firms (WantChinaTimes.com 2013).

While CNPC denied restricting supply in order to pave the way for price hikes in the future, an internal CNPC document obtained by Beijing-based Securities Daily revealed that the SASAC had ordered CNPC to reduce losses from its gas operation before such an action (Song 2013). There is no way to prove that CNPC cut gas because of SASAC, or because SASAC's "order" is in line with their interest. This goes back to the basic question: what is the relationship between the government and NOCs? In his recent work Security and Profit in China's Energy Policy, Tunsjø (2013, p.5) argues that many scholarly works on China's energy security have adopted an "either/or" perspective: "China's energy security is either guided by strategic and mercantilist ambitions or it is shaped by market mechanisms. It is either organised and controlled by the government or it is manipulated by powerful NOCs pursuing their own corporate and commercial interests", but he trusts that a "more or less" perspective is more appropriate and that both market and strategic considerations shape China's energy policy.

While the autonomy of China's NOCs has undoubtedly increased, one can differentiate "corporate autonomy" from "strategic autonomy" (Kong 2009b). The central government is more tolerant to the kind of autonomy that covers daily operations, business planning and investment strategies. But if the government perceives, rightly or wrongly, that NOCs are behaving in a way that carries "strategic" implications for national security and well being, the central government will step in. Houser (2008) concluded that the government could discipline NOCs in three major ways. In addition to regulation (e.g. NEA's approval on major investment) already mentioned above, the government could influence NOCs via broad governance (ownership) and thus personal appointment. As the full owner of NOCs and majority shareholder of their listed firms, the SASAC exercises both basic ownership and strategic ownership rights as their investor. The basic ownership rights the SASAC executes include defining and registering property rights, appraising, verifying and taking stock of state assets and liabilities of NOCs, settling disputes over property rights within these NOCs, and supervising and managing property rights trading. The SASAC also retains the right to oversee major investment and financial planning and development strategy, and even dispatching supervisory panels to the NOCs. In other words, the SASAC has the final say over the most significant issues. Moreover, the government has created some personnel links, or as Lin & Milhaupt (2013) put it, “institutional bridges”, that connect NOCs, SASAC and the central government more organically. For example, there is a routine exchange of personnel between SASAC and the central SOEs it supervises, including NOCs. Kong (2009b) judges that given the control of SASAC over personnel, state assets and major issues, Chinese NOCs retain only operational autonomy and but they lack strategic autonomy in reality. Kong’s insight is correct to some extent, but one should also note that the SASAC also suffers from similar governance challenges with the NEA. The SASAC has only about 800 employees, organised into diverse bureaus ranging from enterprise restructuring to foreign affairs. Although the SASAC is a ministry-level agency and thus its authority problem is less severe than the NEA, 53 of the most important SOEs under its supervision are also ministry-level. It faces potential resistance not only from the firms it supervises but also from the competing agendas pursued by other important ministries (Lin & Milhaupt 2013, p.736). Even more intriguingly, Lin & Milhaupt (2013) find the corporate managers seconded to SASAC are fairly senior and come from leading enterprises, while the SASAC officials are relatively junior, meaning that the exchanges is primarily designed to build SASAC capacity and promote cooperation between the SOE sector and the government, rather than to facilitate SASAC’s monitoring of the SOEs. It also means that the junior SASAC staff are more easily influenced by the former SOE (and NOC) leaders.

Another important way of China’s government to supervise and control NOCs is through the “shadow” governance of the Communist Party (Figure 3.5). By “shadow” it does not imply any conspiracy connotation, but is used to describe both the formal (institutionalised) and informal influence of the Party over NOCs and their legal owner, the SASAC, while these mechanisms are not formally within the normal boundary of the official and corporate governance. Currently, one-third of the employees in the national SOEs are members of the Party, and Party organisations exist within each level of the NOC hierarchy. Institutionalising party penetration of SOE/NOC roles is a formal policy, and overlaps between the two systems appear rather uniform, such that a corporate manager of a given rank typically holds a position of equivalent rank in the party system (Lin & Milhaupt 2013). In the parent NOCs, i.e. CNPC, Sinopec and CNOOC, the Party sets up party groups (*dangzu*), each of which consists of no more than 10 Party members of the NOCs from the core decision-making body from the companies. Membership of these party groups overlaps with the top management personnel in the parent NOCs, and the executive members of the board of directors for their holding firms. The secretary of the party group of the CNPC's Party Central Committee, for example, concurrently serves as President of the company and the Chairman of the Board of Directors for its holding company PetroChina. The Secretary of the party group is directly appointed or removed by the Organisation Department of the Party's Central Committee. Other members of the party group are appointed and removed by the Party's organisation department within SASAC. In the holding subsidiaries, party committees (*dangwei*) are set up to assume the same functions as party groups at their parent companies. Through controlling the top personnel arrangement and major decisions in these party committees and party groups, the Party ensures that its broad policy lines (*luxian*), policy direction (*fangzhen*), and specific policies (*zhengce*) are implemented (Kong 2009b).

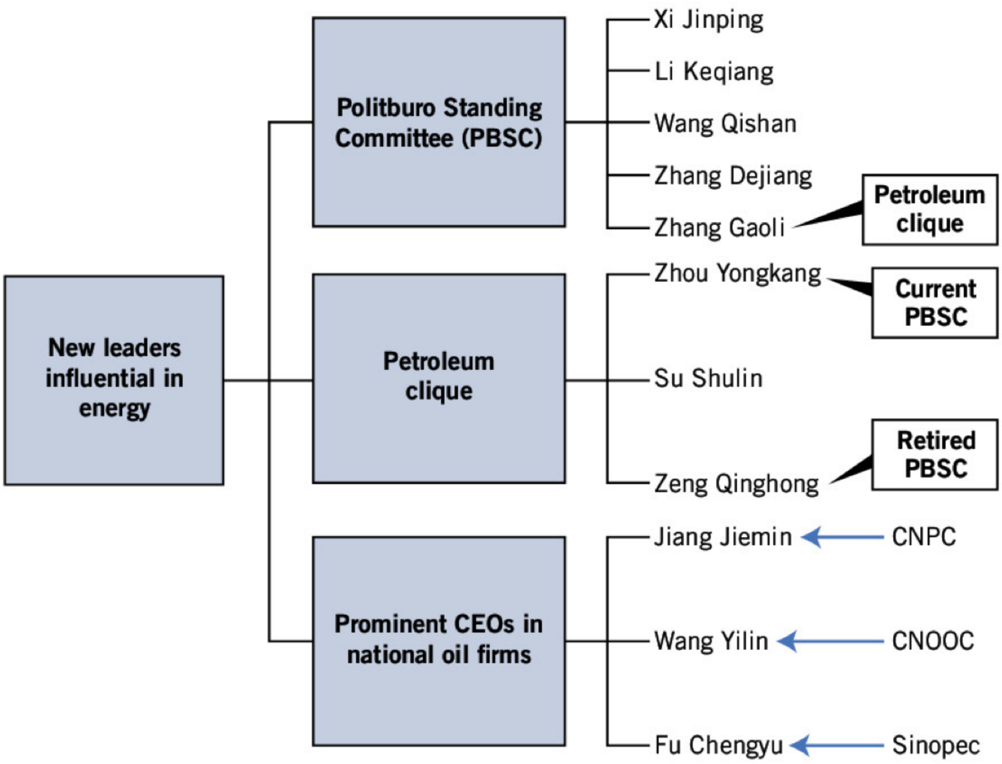
Figure 3.5 China's Party-State Energy Governance



Source: The Author

Adding to an already complicated system is the fact that the central government and the Party reserve a number of positions in several elite government and party bodies for leaders of the NOCs (and other central SOEs), following a policy designed to promote mutual adaptation in political and professional qualities (Lin & Milhaupt 2013). Li (2013) coins the term “oil clique” to loosely refer to a group of politicians who achieved political status through careers in the oil and gas industry. One can reasonable assume that members of the oil clique are more inclined to protect interests of the NOCs and develop network with current NOC leaders and other politicians having similar backgrounds and experiences. When they assume the top positions in the government and the Party (Figure 3.6), it is more likely for them to negotiate for policies more favourable to NOCs, sometimes illegally. Since mid-2013, a growing number of top officials, past and present from NOCs, particularly CNPC, have been detained for investigation on corruption. A network of allegedly corrupt interests appears to have existed between a number of key individuals: (i) between Bo Xilai (the recently imprisoned ex-Party Secretary of Chongqing) and Jiang Jiemin (former head of the SASAC and former President of CNPC/PetroChina), and (ii) between Jiang Jiemin and Zhou Yongkang (who recently stepped down from his positions on the State Council and on the Standing Committee of the Politburo and who was General Manager of CNPC in the mid-1990s). Four other senior managers from CNPC/PetroChina are also under investigation (Andrews-Speed 2013).

Figure 3.6 China's Energy Leadership since 2013



Source: Li (2013, p.52)

In short, while maintaining some public policy responsibilities, China’s NOCs have become more commercially driven and enjoyed increasing autonomy, amid the decentrationalisation and fragmentation of the central energy leadership. The central government, however, retains power and influence to control NOCs over what it sees as strategic issues via SASAC and the Party networks. In the words, there is a top-down boundary of NOCs' activities and planning. At the same time, the leaders of government and the Party can redraw the boundary, and those leaders with strong previous NOC networks can do it in favour of NOCs.

3.5. Conclusion

This chapter has investigated the relational landscape of China's gas production network, focusing on the state, its actors and institutions. It has argued that studies of any industry or sector in China should begin by considering the institutional and supply chain role of state actors and institutions. This is because the underlying structures taking shape around them are nearly always dominated by the governments and SOEs, and fundamentally determine private firms' access to resource (upstream), logistics (mid-stream) and market (downstream). It is especially true in those industries that the state considers to be "strategic", from telecommunications to energy. China's model of development does deviate from the conventional neo-liberal or capitalist path: governments play roles beyond those of a resource-distributing developmental state, serving as a gatekeeper, active market player, and a political, diplomatic and financial facilitator; however, the "state" is incoherent and consists of a range of actors and institutions at a variety of scales and with different, often contradictory objectives. Political and economic reform has brought about a re-territorialisation of the state, via trans-national and sub-national sovereignty arrangements. As a result, national sovereignty has become less absolute: it now allows sub-national variation, and the boundary has become more porous, exposing China to transnational institutions, such as CDM, WTO obligations, international gas pricing, information disclosure requirements by Hong Kong and New York Exchange. In terms of sub-national variations, central government agencies (including those governing energy) have become more departmentalised and decentralised, whereas local governments at the provincial level have been more federalist and protectionist. China is no longer single-minded (if it ever was). Adding to the already complex relational networks associated with natural gas production, distribution and consumption are the powerful NOCs, with their penetrating influence in setting the agenda, capacity to set agendas, dominance in oil and gas supply chains, and their shadow roots of the Chinese Communist Party. NOCs, especially CNPC and Sinopec, are politically superior to many central government agencies, including those that are supposed to govern them. To struggle for stronger political power, NOCs are competing with each other by maximising their market shares and profits both at home and abroad. A de facto "co-governance structure" has been formed between the state and NOCs, in which NOCs both affect, and are affected by, national energy policy and measures. The following chapters will show that NOCs' exclusive access to gas resources, importing rights, and transmission infrastructures have given them unchallenged positions in the upstream and mid-stream (see Chapters 4 and 5). But given the vested interests of the local governments, the distribution and marketing of gas (downstream) is much more fragmented with significantly more non-NOC market participants (Chapters 5 and 6). The following chapters will also show how although NOCs have become more powerful and autonomous from the central government, they remain strategically controlled and governed by the top decision-makers in the government and the party. For example, Chapters 4-5 will explain how NOCs have suffered losses from centrally regulated pricing, and how Sinopec has failed to viciously acquire China Gas.

Chapter 4 Acquiring Gas

4.1. Introduction

As noted in Chapter 1, natural gas transition, as is energy transition in general, can be understood narrowly or comprehensively. It can refer to the gasification of a country's energy consumption structure, implying a rise in the share of natural gas in a country's primary fuel mix. It can also refer to the gasification of a country's energy supply-chain system, implying (i) commodificaion of raw natural gas, (ii) infrastructure expansion and upgrade for gas imports, distribution and storage, (iii) marketisation and regulation, as well as (iv) an increase in end-use consumption of natural gas. In short, the gasification of China's fuel mix requires, or results from, the gasification of China's energy supply-chain system. While Chapter 3 has unpacked the overall relational landscape of China's gas production networks, formed by actors and shaped by institutions at a variety of scales, the following three chapters scrutinise the upstream, mid-stream and down-stream parts of the supply chain respectively. In contrast to traditional GCC/GVC approaches, a GPN understanding of the supply chain not only underlines (i) functional, organsational, institutional and political connections among a range of state and firm actors in and across space in each component; it also highlights (ii) the dialectic relations between components in the chain. Rather than the production network imagined as a one-way, linear process of input-output, the analysis in the next three chapters recognizes that components in the network cannot be fully understood separately. Accordingly this chapter, while discussing how China "acquires" gas to realise its gasification plan, consciously links the upstream to the mid- and downstream.

In the energy literature, a country's "gas supply" very often means only the country's total domestic gas production and net imports. This territorial conception is deeply rooted in the geographical imagination of Chinese policy-makers, with significant implications for the country's interpretation of "energy security". In my interview with a National Energy Administration (NEA), I asked why they do not regard such issues as electricity and gas shortages as "energy security problems" in their China's Energy Policy White Paper 2012. They explained (Interview 3):

> We need to ask 'energy security for whom?' Our country does not really have an electricity supply problem. Although we sometimes face some power shortage problems during peak seasons

> and in some provinces, these problems are short-lived and localised, and most importantly, these problems can be solved by ourselves. Oil imports are different. If our oil imports are cut off, it affects the whole nation, not just certain provinces, and we no longer maintain zili gengsheng (self-reliance). . . .Natural gas is an emerging issue of energy security because its import dependency and its role in China's fuel mix are climbing quickly. . .If China were heavily dependent on coal imports, coal could also have been an energy security issue.

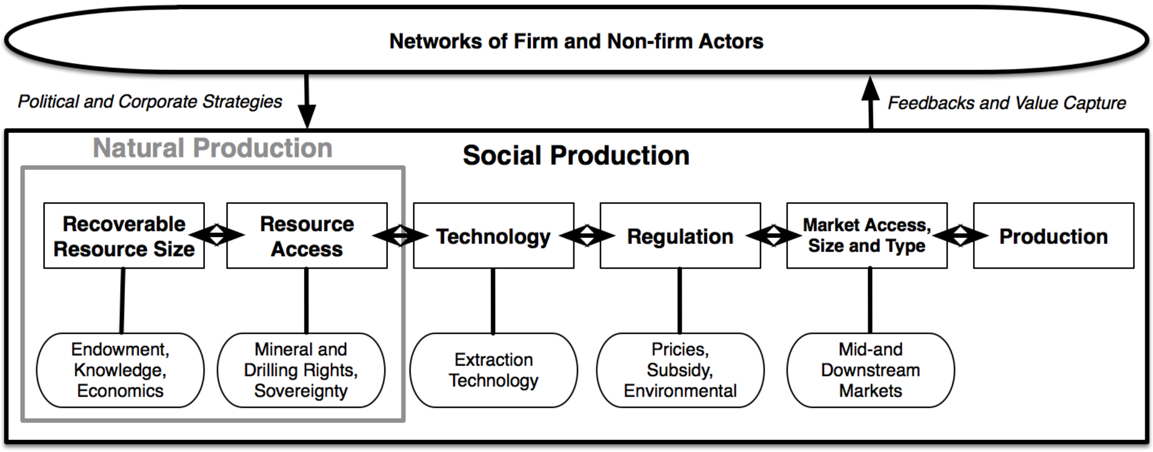
Their explanation vividly reflects their geographical imagination associated with "energy supply", which assumes that as long as China can acquire a sufficient amount of energy, there will not be real supply problems within China. The misconception is that energy acquired will necessarily be supplied to consumers. This misconception underpins the current version of China's energy security policy, which highlights the potential vulnerability of oil imports (as more than half of the oil China consumes is imported) but seriously overlooks the potential for supply disruption at the sub-national scale (Leung et al. 2014). A GPN understanding of the security of gas supply in China, however, pays equal attention to how China acquires gas through domestic production and imports, and how it distributes the acquired gas to consumers via pricing. While Chapter 4 explores the acquisition of gas sources and Chapter 5 analyses the mobilisation, marketisation and regulation of gas sources, both chapters are tied to the theme of gas supply, which is the material prerequisite for China's gasification of energy structure.

The rest of the chapter is structured as follows: Section 4.2 conceptualises the gas hydrocarbon chain and confirms the GPN perspective that the extractive sector, unlike manufacturing and services, depends not only on social production but also on natural production. It will explain how the dependency of gas extraction on natural resources has led to the spatial monopoly enjoyed by the NOCs, creating challenges of resource access. It will also explore how the non-extractive parts of the supply chain, such as market access and regulation, have shaped, and been shaped by, the extractive sector. The section concludes with a case study of CBM to shed light on the social institutions of resource access and their implications for gas production. Section 4.3 investigates the "conditionality" of a strategic coupling between international gas players, i.e. vertically integrated firms (e.g. Shell) and oilfield service firms (e.g. Schlumberger), and China's regional institutions, by focusing on conventional and unconventional gas. It also introduces the case of shale gas to illustrate an argument that unconventional gas is associated with a new form of "regional institution" that is better able to "hold down" the gas GPN. Section 4.4 discusses the external linkage of gas flows into China and explains how official concerns about geopolitics and energy security have been so integral to China's gas trade. Section 4.5 summaries the major findings and underlines the links between these findings and other chapters.

4.2. Domestic Gas Production

The history of China's gas production, as in any other countries, reflects the fact that the commodification of a natural resource involves a collection of social-technical relations that form a network of production. Figure 4.1 captures the dynamics of gas production network in a schematic way. It adapts the "social production" concept of a hydrocarbon commodity chain proposed by Bridge (2008), and the premises of GPN that there are interactions between different actors in the upstream, midstream and downstream of a commodity chain. This section investigates the natural and social production of China's natural gas, while the next section unpacks the topology of the actors involved, and the possibility of strategic coupling between international gas players and domestic actors and institutions.

Figure 4.1 A Schematic Approach to Gas Production Network



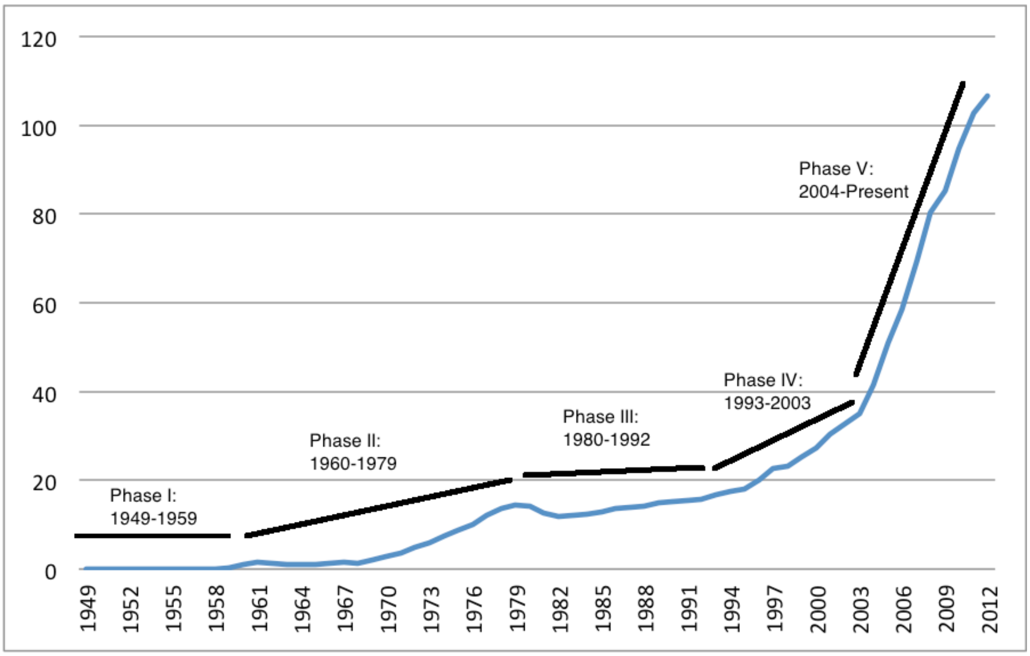
Source: The Author

4.2.1. Finding Resources

The first stage of gas extraction is to find gas resources and evaluate the size of commercially recoverable reserves. Natural gas, like other natural resources, is only partially socially produced: the extractive sector relies on natural production to a degree not found in manufacturing and service sectors. The geological and geographical attributes of natural gas in a given region fundamentally affect the presence, size and location of any gas production activities. However, estimating a country's gas resources and reserves is both an art and science. Physical/geological endowments of gas - technically called original gas-in-place (OGIP) – vary with technology, knowledge and cost, and so no estimates of OGIP can be regarded as 'final'; instead, gas producers keep revising their estimates with changes in knowledge, costs and technology. According to a national survey published in 2005, China's gas resources amounted to 56 trillion cubic metres (Tcm) prospectively and 35 Tcm geologically (Higashi 2009). The actual recoverable resources were estimated at 22 tcm, which is 70 per cent higher than the previous study conducted in 1994 (Higashi 2009). The Chinese classification of energy resources is not strictly compatible with international ones such as SPE, AAPG, WPC and SPPE, and thus it is not always clear what "recoverable resources" mean. However, one can reasonably assume that it refers to gas that is technologically recoverable, but not necessarily commercially extractable (Wang et al. 2013). Indeed, it is the "commercial deliverability" of natural gas rather than its "physical availability" that is more central to the geopolitical economy of gas. The industry traditionally classifies gas that is both technologically and commercially recoverable as "reserves", which is more subjective, socialised and dynamic than "resources".

China's gas production has grown over the past decades primarily as a result of increased administrative and commercial efforts by government and the national oil companies (NOCs) to finding gas resources and reserves. China is now the world's fifth largest gas producer: output in 2012 was 107 Bcm or 3.2 percent of the world's production (BP 2013), significantly larger than the production level of 0.007 Bcm in 1949 when the People's Republic of China was founded. It can be said that China's gas production has experienced five main periods of development (Figure 4.2). After the founding of the country, the government launched a "socialist reconstruction" programme, which saw a modest increase in gas production from 0.007 Bcm in 1949 to 0.29 Bcm in 1959, the year that the giant Daqing oilfield was found. The discovery and development of Daqing oilfield and the subsequent large gas-associated oilfields such as Shengi and Huabai led to a surge in gas production. Gas production in 1960 reached 1.04 Bcm, 3.5 times the 1959 level (Fridley 2008). During 1960-1979, gas production grew at a rate of 23 percent per year and reached the first historical peak of 14.51 Bcm in 1979. This extensive growth in gas production was actually not intended primarily, but was a by-product of the rapid development of China's oil industry since the early 1960s – in response to the imposition of oil import embargoes. In the 1950s and the 1960s China relied on oil imports from the Soviet Union that were discontinued for political reasons in the early 1960s. During the 1960s and 1970s, i.e. the second stage, China's oil supply also suffered from the U.S.-led trade blockade (Leung et al. 2014). Devoid of modern technology and knowledge for oil exploration and production, China's response was to announce "the battle campaign of oil". Thousands of men were mobilized to explore for oil in "battle" formation, controlled by military work methods, and driven forward by Maoist ideology of *zili gengsheng* (self-reliance). To carry on this strategy the State Council required all relevant ministries (transport, machinery, construction, railroads, agriculture and forestry) as well as the relevant provincial governments, to cooperate under the umbrella control of the Ministry of Petroleum Industry (MPI). In the case of Daqing, up to 40000 workers were mobilised in the Daqing development to perform every task, from the basic construction of accommodation to the transportation of machinery, often by means of long human chains (Kambara & Howe 2007). The growth of gas reserves and production during the command-economy era was underpinned by rigid and widespread government control. This extended not only to the upstream component but also to the rest of the supply chain, including transmission, distribution and consumption, as gas output was centrally allocated to industrial consumers, mainly the oil and gas bureaus for self-consumption and to fertiliser manufacturers.

Figure 4.2 China's Gas Production, 1949-2012

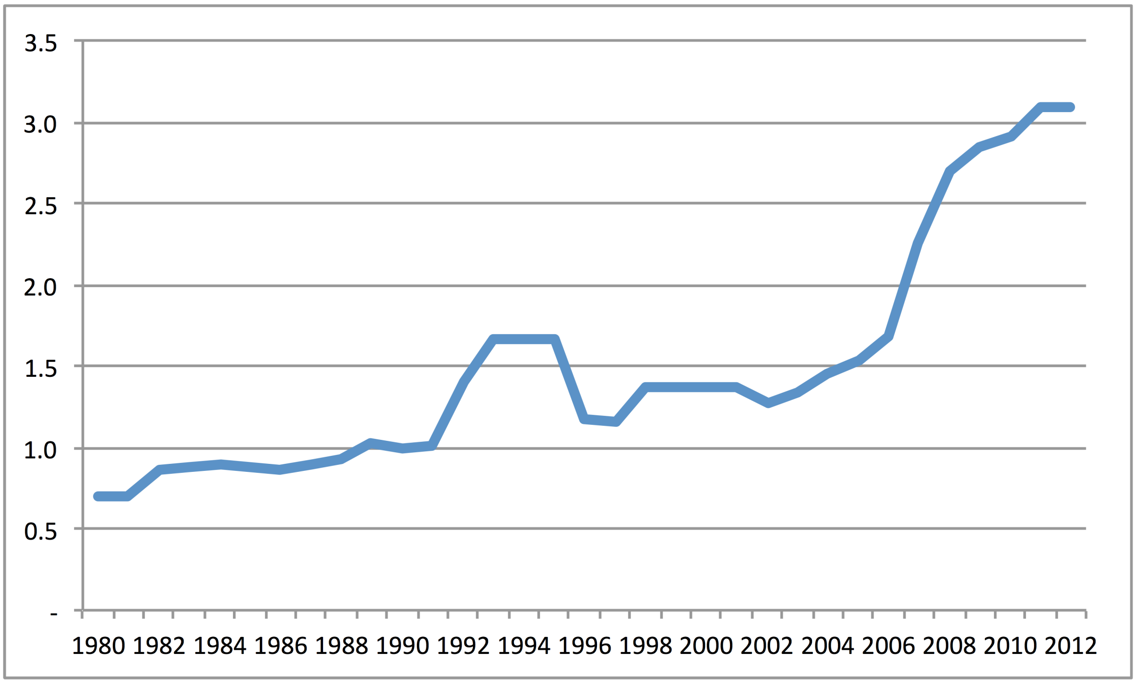


Source: CEIC (2014)

The implementation of China's economic reforms in the early 1980s (announced in late December 1978) marked a third stage of gas development, characterised by rationalisation of the oil and gas industry. The central government introduced a two-tiered pricing system of "quota" and "above-quota" prices, both of which were set by the state. Producers were allowed to sell "above-quota" outputs at higher prices, thereby encouraging producers to increase efforts to explore for gas resources. The subsequent gradual increase in average gas prices has also increased the size of gas reserves (i.e. commercially feasible). In the 1990s, faced with a newly-kindled anxiety over energy security after China became a net importer of oil in 1993 (Leung 2010), together with concerns about CNPC's financial losses and low world oil and gas prices, the central government decided to raise domestic outputs. It did this by increasing domestic oil and gas prices sharply, and increasing NOC investment in exploration of gas reserves (and opening up foreign company participation). CNPC quickly returned to profitability in 1994 (Fridley 2008).

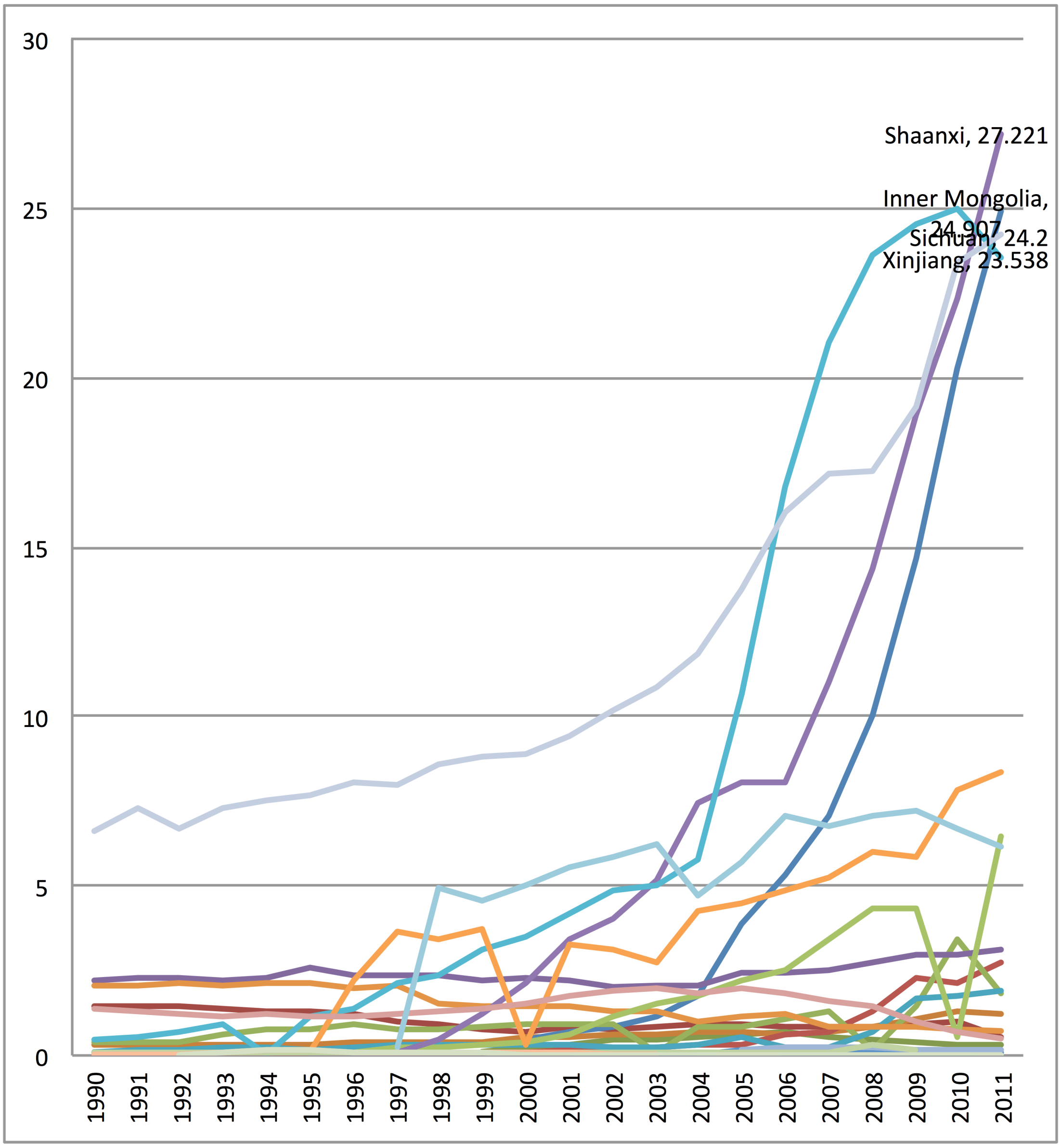
A fourth phase was characterised as "supply chasing demand", as the supply increased much faster than the size of China's gas market, which explains the decline of gas reserves in the second half of the 1990s (Figure 4.3). In response, the central government, for the first time, promoted natural gas as a cleaner alternative fuel to coal. Restrictions on gas-fired power generation were also partially lifted (although gas-fired base-load generation remains severely restricted; see Chapter 6). To develop a gas market, however, requires delivering gas to the market and in this period significant pipeline infrastructure was developed. For example, the Shaanxi-Beijing Pipeline, one of the first major long-distance transmission pipelines, was constructed in 1997 in order to raise gas use in the residential, power and industrial sectors in Beijing. The approval of West-East Gas Pipeline (WEGP) in 2002 (detailed in Chapter 5) marked the beginning of a new fifth stage and represents a watershed in the contemporary history of China's gas industry. China's proven gas reserves started to climb fast after 2002, due to the increased exploratory efforts in uncharted or less developed regions, such as Xinjiang, Inner Mongolia and Shaanxi. Although gas reserve data by province are not available, gas production trends by province depicted in Figure 4.4 confirm that gas reserves in these three regions started to surge around the launch of the WEGP. The discovery and development of these three new gas regions, together with the traditional gas-rich region of Sichuan, now account for more than 70 percent of China's total gas production (Figure 4.5).

Figure 4.3 China's Natural Gas Proven Reserves, 1980-2012 (Tcm)



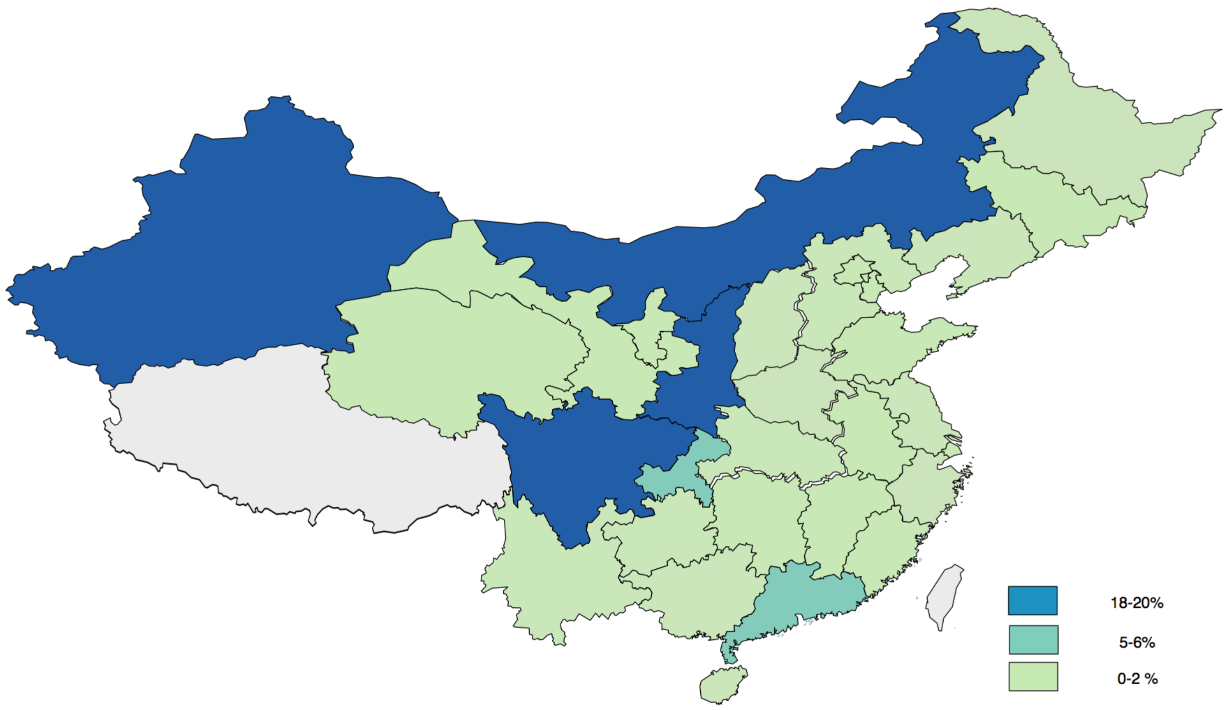
Source: BP (2013)

Figure 4.4 China's Gas Production by Province, 1990-2011 (Bcm)



Source: Lawrence Berkeley National Laboratory (2013)

Figure 4.5 Geographical Distribution of China's Gas Production, 2011



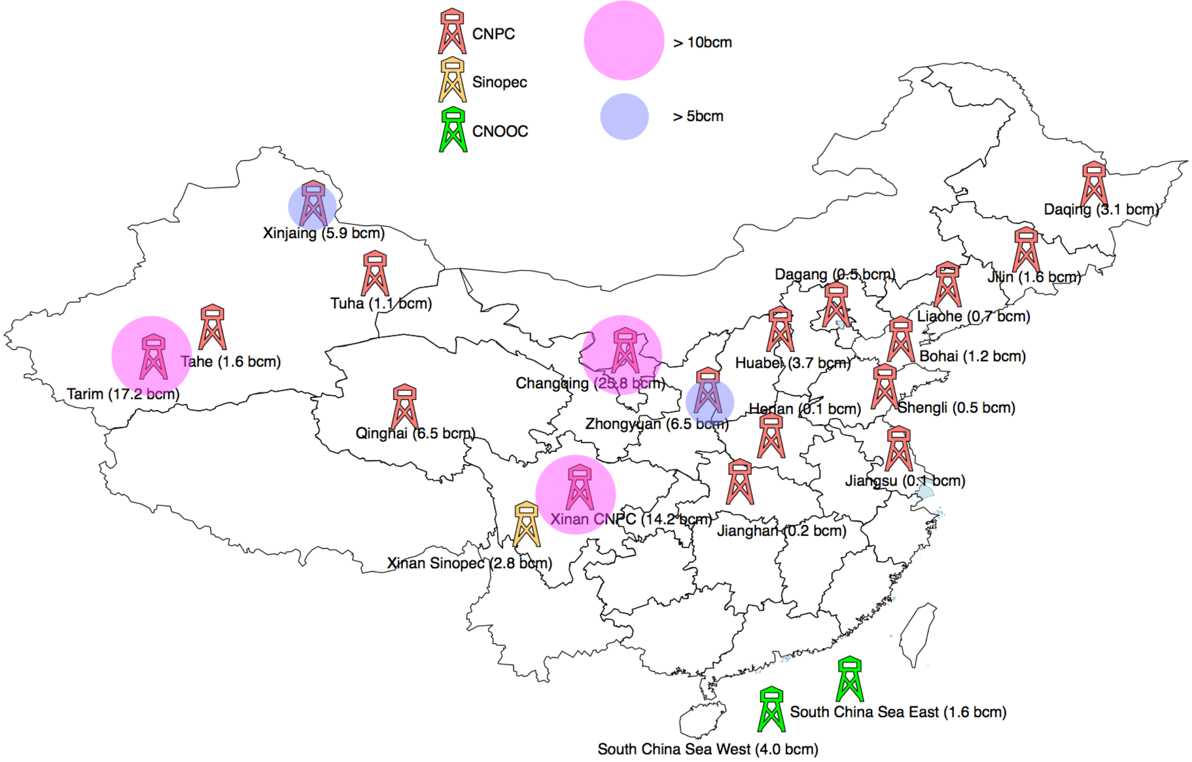
Source: Data from Lawrence Berkeley National Laboratory (2013)

4.2.2. Resources Access, Resource Quality and Technology

Once producers are certain that the resource size of a given region is large enough to deliver production economies of scale, they need to gain access to the resource. As noted in the previous sub-section, the dependency of natural gas production on natural production limits the spatial flexibility of the network to an extent not founded in manufacturing and service sectors. The materiality of gas produces differential rent that can be captured by firms via spatial monopoly, i.e. ability to exclude other firms. Obtaining resource access is a challenging task for firms that have no immediate connections with the government, who plays the role of gas landlord. In most countries around the world, including China, it is mainly governments that own mineral resources. Even in Western societies where private landowners or communities can own the surface of lands, the subsurface resources typically belong to the state. The commonly quoted story of US shale gas constitutes an exceptional case of "vertical sovereignty" (Bridge 2013): in the US, hydrocarbons, except those on federal lands, are not reserved to the government but to individual landlords. The different institutional arrangements in the US and China mean that gas developers need to secure resource access in different ways. In the US, since a landlord clearly owns the respective mineral rights, the benefit that landlord can count on will be an incentive for development. Private firms need only to negotiate with individual landlords to gain access: if those landlords agree access terms, firms can in principle start exploring and exploiting the gas (subject to environmental and other permitting). In this case, constraints on access come mainly from local communities on social and environmental grounds, as some residents are worried about the potential water and land contamination of shale gas production. While straightforward in principle, a lot of interesting politics, struggles and negotiations pervade the process of mineral rights acquisition in the US, and different interests use a variety of ways to promote their agendas and argue against others.

In socialist states such as China, legally speaking, all lands and their underground mineral resources belong to the central government or the state. In December 1950, the State Council promulgated the "Regulation on the Mining Industry in the People's Republic of China", which specified that the country's mineral resources, including oil and gas, were state assets and should be managed by the central government (Zhang 2004). The Ministry of Land and Resources (MLR) oversees the surveying, planning, management, protection and sustainable use of China's natural resources, including natural gas. Given that the NOCs were created out of the central government in the 1980s, these companies inherited all conventional gas resources of China and they have little incentive to share them. Figure 4.6 displays China's gas production by gas field and company, and shows how the NOCs are virtually the only gas producers, due to their exclusive access to gas resources. Non-NOC producers do exist, but they are legally required to form JVs with NOCs to have access to gas resources, and their equity share must not exceed 50 percent (see Section 4.3).

Figure 4.6 China's Gas Production by Company, 2012



Source: Data from CNPC Economics & Technology Research Institute (2013)

4.2.3. Regulation and Market Access

Market access is also critical in deciding whether or not potential gas producers will explore and extract gas. In other words, unless producers are certain or reassured that the gas can be sold to the market, they will not produce any - or at least not produce gas as a commodity. In the latter case, the gas produced from oil production activities might be vented, flared or injected back to the oilfield. The development of the mid-stream and forms of gas pricing, discussed in Chapter 5, are highly significant for gas production. The Chinese gas experts, therefore, generally agree that the problem of regional discrepancies between gas supply and demand may be solved by expanding distribution infrastructure, from regional transmission pipeline and inland small-scale LNG/CNG logistics system to local distribution pipelines. Currently, the central government allows only the NOCs to construct and operate regional transmission pipelines. With deep pockets and political connections, they can fast-track mega pipeline projects, but such an approach is not flexible enough for unconventional gas development. Shale gas and CBM are risky businesses, and investors are discouraged if pipelines to markets are not in place or planned and, because of the NOCs' monopoly on transmission pipelines, they are not allowed to build and design pipelines that fit their needs. To get around the regional pipeline problem, China is running a remarkable business of inland small-LNG/CNG. Since inter-provincial gas pipelines remain dispersed and scattered in China, small-LNG/CNG plants are a way to fill this gap by liquefying the gas that does not have access to pipelines and transporting it to customers across the country with LNG-carrying trucks (Shi et al. 2010). Different from the case of regional pipelines, independent investors are allowed to build and operate the inland LNG/CNG businesses; in fact, Chapter 5 will show that the supply chain of this sector is much more diverse in terms of the number of players. The quickly emerging new market in natural gas vehicles (NGVs), discussed in Chapter 6, will add further momentum to the LNG/CNG industry. Moreover, as a response to the WTO obligation, the government started to liberalise the local gas distribution industry (a.k.a. the city gas industry) in 2002. As a result, local governments and private firms have contributed significantly to the expansion of local pipeline networks, thereby expanding the gas market.

4.2.4. Case Study: Mineral Rights Conflict over CBM

The mineral rights conflict around CBM in China provides a representative illustration of the political economy of resource access and regulation, and how has it affected the development of the industry. Given that CBM can be found almost anywhere there is coal (Al-Jubori et al. 2009), conflicts take place when the mining rights of CBM and coal do not belong to the same actor. Technically the terms CBM and coal mine methane (CMM) refer to the same methane found in coal seams, but the former refers to the methane recovered through surface drainage while the latter refers to the methane recovered through underground capture (Lin 2011). Chinese laws and plans do not differentiate CBM and CMM in legal terms but regard them as the same resource, and list them as "CBM (CMM)" or just "CBM" in official documents. This section uses "CBM" as a collective term to refer to the gas found in coal seams, regardless of the type of recovery; however, it argues that the legal mineral rights conflict between CBM assigned to the central government or SOEs, and CMM assigned to the local government or coal firms is the primary reason for the slow development of China's CBM industry.

While tight gas is not considered unconventional gas by the Chinese government (see next section), it is CBM rather than shale gas that is the main driving force behind unconventional gas production at the moment (Chen 2013, Gao 2012). In 2012, CBM production accounted for 12 percent of total gas production, after conventional gas and tight gas (Table 4.1). Being a coal-rich country, China has the world's third largest CBM resource, mainly located in the Ordos basin (in Shaanxi province) (Figure 4.7). Geological resources of coalbed methane in the North, Northwest, South and Northeast China account for 56.3 percent, 28.1 percent, 14.3 percent and 1.3 percent respectively of total geological resources of CBM in China. In terms of the vertical profile, geological resources of CBM less than 1000m deep, between 1000m to 1500m and from 1500m to 2000m account for 38.8 percent, 28.8 percent and 32.4 percent respectively of China's total geological resources of CBM (Sino Oil and Gas Holding Ltd 2014).

Table 4.1 China's Gas Resources and Production by Type, 2012

	2012 Outputs	**Technically Recoverable Reserves**
Tight Gas	32 Bcm	12 Tcm
CBM	12.5 Bcm	10.9 Tcm
Shale Gas	0.5 Bcm	25.1 Tcm
Conventional	61.7 Bcm	32 Tcm

Source: Chen (2013, p.26)

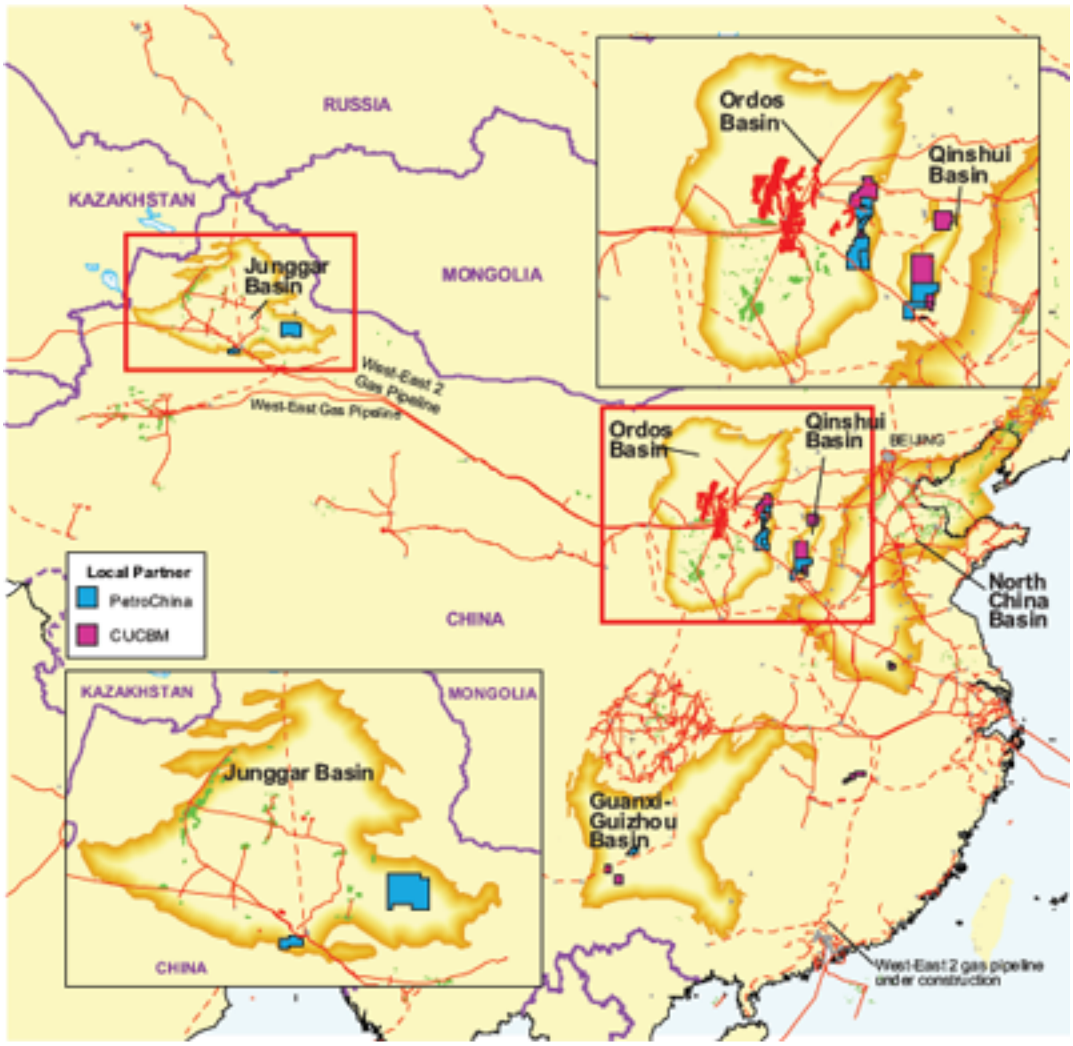
Figure 4.7 Distribution of China's CBM Resources

Source: Sino Oil and Gas Holding Ltd (2014)

China started removing CMM from its coal mines as early as the 1950s following the start-up of its coal industry. For a long time CMM was not considered as an energy resource but as a hazard, one that continues to kill hundreds of coal miners every year (593 in 2010 (Lin 2011), and so roughly 15 Bcm of CMM are vented or flared for safety reasons (Gao 2012). But in 1996 the government officially announced that it would develop a CBM industry, trying to turn it into a usable fuel. A monopoly company, China United Coalbed Methane Co. (CUCBM), was established in 1996 by the then Ministry of Coal Industry (later the Ministry of Geology and Mineral Resources and CNPC) to explore, develop and produce CBM. The company saw the first commercial gas flow in Qinshui Basin, Shanxi Province in 2006. Starting from the first success in 2006, CBM development began to attract attention and enthusiasm from the NOCs. This also reflected China's involvement in a series of Clean Development Mechanism (CDM) projects for the development of CBM in 2006 (Fridley 2008). CNPC withdrew from its JV with China Coal in CUCBM and founded its own subsidiary company PetroChina Coal Bed Methane

Ltd. in September 2009. Though being a late-comer, it managed to catch up and even exceed its competitors in terms of production (Gao 2012) (Figure 4.8).

Figure 4.8 CUCBM and PetroChina's CBM Activities



Source: Thompson (2011)

There was a time when investors believed that China's CBM would have developed quickly, as it enjoys a number of favourable factors, including a large resource base, preferential policies, accessible facilities and services, foreign technology support and the political support of central government. However, CBM output in 2010 was only 8.6 BCM and failed to meet the target of 10 BCM set by the 11th Five-year Plan. Gao (2012) attributes this failure to a lack of financial backing, insufficient pipelines, poor geology (compared with the US), lack of expertise and skills, and disputes over mining rights for coal mining and CBM development.

Although the mining rights dispute was not the primary reason for the industry to miss the official production target, given that "the undisputed blocks are large enough to keep each CBM producer busy" (Gao 2012, p.13), many agree that these conflicts will be a major obstacle to large-scale development. My informant from CUCBM even argues that this is the biggest deadlock, as infrastructure can be built fast, but reforms that involve vested interests would be more challenging (Interview 6). In theory, the over-lapping of coal and CBM mining rights mean that both CBM producers (central actors) and coal producers (local actors) cannot carry out production activities until conflicts are settled, because there is no way to mine coal without venting/flaring/capturing/commodifying the CBM/CMM, and vice versa. In practice, backed by the local governments politically, coal-mining firms (often local SOEs) go on producing coal and, to the eyes of CBM firms, steal or jeopardise the CBM resource. He went on to explain that the central government is of course aware of this deadlock and the State Council issued "A Few Opinions on How to Speed Up CBM Prospecting and Utilisation" (State Council General Office [2006] No.47 Document) to suggest the "combination of gas drainage and coal mining" (Lin 2011, p.10). The reform appears to be beneficial to coal mining firms owning coal mining rights, as they will not be punished for what the central oil and gas firms deem as illegal production: instead, they are given an opportunity to conduct equal negotiation with CBM mining right owners. In practice, neither CBM producers nor coal mining companies will want to give up that to which they are legally entitled, and there is so far no mechanism to solve the impasse. To make matters worse, there are reports of some local companies, such as Jincheng Coal Group in Shanxi, recovering CBM illegally and selling it local residents as CBM transport fuel via pipelines they built. Eventually they have gained strong political support from the local government (as it helps improve local air quality) and from local residents (as CBM is 40 percent cheaper than gasoline in that part of the province) (Lin 2011).

4.3. Conditionality of Strategic Coupling

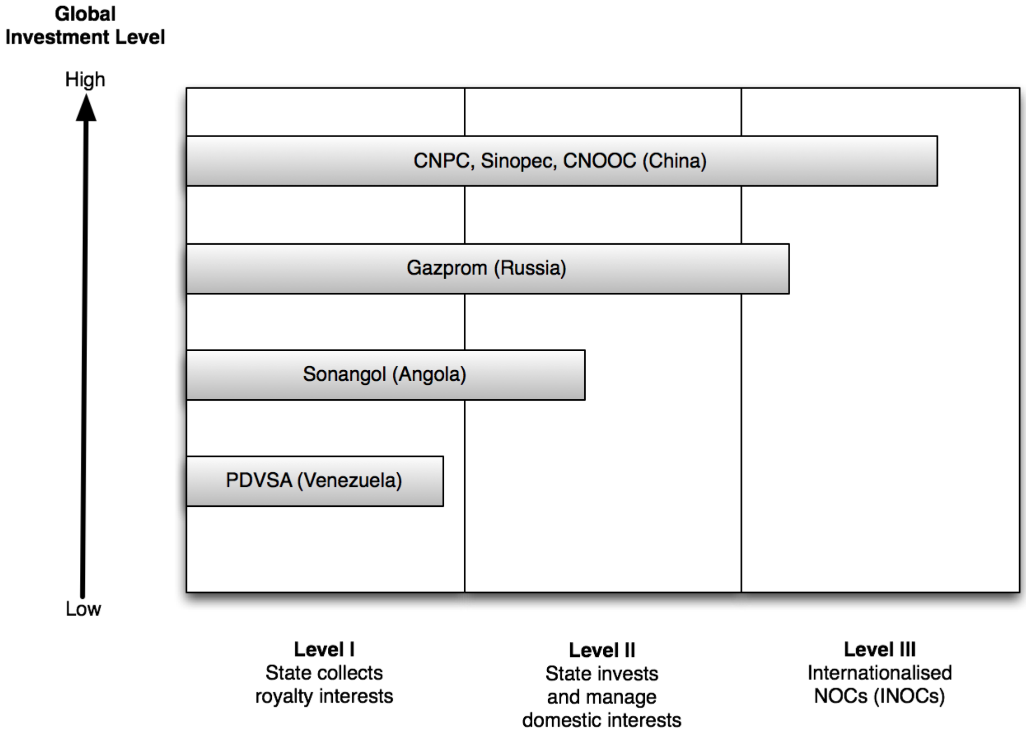
Viewed from a GPN perspective, natural resource endowment provides an important "regional asset" and, if these resources provide economies of scope and economies of scale that can deliver regional advantages, the pre-conditions for development. However, this happens only "insofar as such region-specific economies can complement the strategic needs of trans-local actors situated within global production networks" (Coe et al. 2004, p.471). In GPN terms this is a process of "strategic coupling". In the case of natural gas, trans-local actors include the IOCs that have "strategic needs" for reserve replacement, and international oilfield service (OFS) providers that have interests in expanding their client base and diversifying their portfolios. However, as the above analysis suggest, virtually all conventional gas resources are exclusively controlled by the NOCs. The resource access problem, together with techno-nationalism mentality discussed in Chapter 3, have weakened the institutional capacity of China to "hold down" the a global production network for gas. This section will argue that the unconventional gas sector, especially shale gas, has created an opportunity for IOCs and OFSs to engage in the exploration and production of gas in China. This suggests that there is some conditionality of strategic coupling, as the prospects of "strategic coupling" varies according to the type of gas in question, and the form of cooperation, e.g. equity-ownership or not. The section will also highlight the strategic needs of IOCs go beyond only reserve replacement, as the below analysis holds that IOCs do not find the gas E&P sector in China very profitable, but they also rest on the strategic needs of IOCs to establish trust with the NOCs for partnerships in other parts of energy supply chain within China (e.g. petrol stations and LNG trade) and outside China (e.g. joint-ventures in LNG projects, and mergers and acquisitions of international energy assets). The discussion on OFS will show how the techno-nationalism – e.g. worries about the leakage of geological data, protection of NOCs' in-house oil field services – has hindered international OFS firms from setting foot in China's extractive sector. Finally, the case study of shale gas will explain how its technological requirements and the official opening-up of some shale gas acreage to non-NOC firms have created opportunities for strategic coupling.

4.3.1. IOCs

IOCs refer to the vertically integrated oil and gas firms that run multinational businesses (an "international energy company" is therefore a more accurate term). The term is usually used to describe the largest oil and gas companies, such as ExxonMobil and BP, but could also include smaller firms such as Eni. IOCs usually operate in partnership with NOCs in the NOCs' host country, simply because over 90 percent of the world's remaining conventional oil and gas reserves are controlled by NOCs and their host governments (Tordo et al. 2011). Since decolonisation and rise of resource nationalism in the 1970s, reserve replacement and expansion remain the most critical and challenging tasks for the resource-seeking IOCs. In 2011, Foreign Policy published an article about the identity crisis of ExxonMobil. By 2010, although ExxonMobil was still widely regarded as a member of the "Big Oil", its natural gas reserves (53 percent) overtook oil (47 percent) on a calorific basis (LeVine 2011). The implication is that it is now difficult for IOCs to obtain access to oil reserves, as they are being turned away by resource-holding states, which want to produce their own oil. The implication of “reserve placement” is that if IOCs want to stay in business and survive, they need to keep finding new oil or gas sources to replace the reserves they have produced and sold. IOCs have generally been shifting to natural gas, as NOCs normally do not have enough managerial know-how, technology and capital to establish a value chain to produce their gas resources and get the gas commodities connected to the semi-integrated global gas markets. The capital requirement for gas trading infrastructure also motivate NOCs and their host governments to partner with IOCs to hedge risks. The unconventional gas resources across the world, which require technology and innovation of IOCs, are likely to accelerate the process of turning “Big Oil” into “Big Gas”. IOCs such as Chevron, ExxonMobil and Shell are experiencing such a transition.

Although reserve replacement is one of the reasons for IOCs to work with NOCs, IOCs have had very little success in China’s extractive sector, in which Chinese NOCs are powerful and reluctant to share their reserves. Scholars such as Ledesma (2009) and Inkpen & Moffett (2011) hold that the development levels of NOCs are significant in determining value-sharing opportunities for IOCs. They propose a three-tier scheme to catorgorise NOCs according to their internationalisation levels and designated functions (Figure 4.9). The degree to which an NOC grows and expands is a function of a government’s aspirations, as well as the level of risk that the government is willing to take (Ledesma 2009). Through interviews with industry informants, Ledesma (2009) investigates the changing relationship between NOCs and IOCs and finds that although the actual changes vary geographically, the long-standing argument about the "obsolescing bargain" between firms and host states remains true. According to Vernon (1971), relative bargaining power is assumed to initially favour the firms (IOCs) as they can choose to invest in several locations and are therefore relatively mobile, or they have capabilities and resources to extract raw materials that the host states do not have. So host states have to offer locational incentives to attract them to invest and, in GPN terms, to “hold down” the gas GPN. The initial bargain between investing firm and host state, however, "obsolesces" over time. Once a firm has made investments in the host country, the committed capital can be held hostage by opportunistic states.

Figure 4.9 Levels of Development of NOCs



Source: Modified from Inkpen & Moffett (2011)

This "obsolescing bargain" argument, however, is not entirely applicable to China, because the Chinese government and NOCs have always had limited cooperation with IOCs and OFSs, even in the early years of China's oil industry when the NOCs were less mature and developed. They have adopted a "self-reliance" mentality since the founding of the country during the Cold War, meaning that they do not resort to "imperialist" foreigners unless they have to. Such mentality was reinforced when the West imposed an embargo on China during the Korean War in the 1950s, and when the Soviet Union cut off China's oil supplies in the 1960s. My informants from Schlumberger and NEA confirm such an observation (Interviews 3 & 8). Studying the case of renewable energy, Andrew Kennedy rightly points out that a mentality of "techno-nationalism" pervades China. The concept "techno-nationalism" refers to "the belief that technology is a fundamental element in national security, that it must be indigenised, diffused and nurtured in order to make a nation rich and strong", or "the desire of Asian states to free themselves from dependence on western technologies" (Kennedy 2013). Techno-nationalism, however, should not be interpreted too strictly. In fact, China and other Asian countries have adopted a mix of nationalistic and liberal policies in pursuit of national technological goals. Terms such as "neo-techno-nationalism" or "open techno-nationalism" were coined to refer to "the pursuit of national technological goals through a combination of greater state activism and more openness toward foreigners" (Kennedy 2013, p.912). Kennedy (2013) distinguishes between "ideological" and "instrumental" techno-nationalists and the latter, like post-Mao China, believe that government policy should be sufficiently flexible to exploit opportunities to obtain technology from abroad, even as they distrust foreign suppliers over the long run.

China needs IOCs in areas where NOCs cannot deliver. Whereas onshore oil production in China is mostly limited to CNPC and Sinopec, IOCs have been granted greater access to offshore oil prospects and unconventional gas fields, through joint ventures (JVs) and production-sharing contracts (PSCs) (U.S. Energy Information Administration 2013). Although there is a lack of public data, it is believed that a PSC is the most prevalent form of IOC-NOC cooperation in China, as a JV implies joint ownership of assets and concession rights, which the Chinese government and NOCs are more reluctant to accept in the E&P sector (JVs are much more common in the downstream). According to China's regulation on PSC, PSCs are won by the foreign enterprise either through negotiation or with an invitation to bid from one of the NOCs, followed by approval from the Ministry of Commerce (MOFCOM). Under a PSC, the NOC acts on behalf of the government to grant the IOC exclusive rights, subject to supervision, to explore for gas in a defined geographic area called a "block". Unlike concession agreements which are not adopted in China, under PSCs, the IOCs has no ownership rights of minerals in the ground, which leaves them potentially vulnerable to political instability (Blumental et al. 2009).

The contract term of a PSC is divisible into three separate periods: (i) exploration, (ii) development, and (iii) production, with the parties' obligations differing during each period. The exploration period is divided into three phases, usually lasting seven years in total, and if there is no commercial discovery by the expiry of the first or second phase, the PSC can be terminated by the IOCs. The development period begins when the Joint Management Committee (JMC) (formed by representatives of both NOCs and IOCs) and the Chinese government approve the overall development program, after confirming that seismic evidence has proved the commercial potential of the gas field. The production period starts on the date of commercial operations. In a typical PSC in China, the IOC will initially be the operator, but the NOC may subsequently succeed as operator either prior to the full recovery of development costs with the approval of the JMC, or at anytime after the full recovery of development costs (Blumental et al. 2009). Currently, IOCs involved in offshore E&P work in China include: Conoco Phillips, Shell, Chevron, BP, Husky, Anadarko, and Eni among others (U.S. Energy Information Administration 2013). The official statistics seem to mask the volume of gas production by IOCs, probably because the IOCs produce gas as NOC's joint venture companies, and Chinese NOCs must hold the majority participating interest in a PSC. According to Business Monitor (2013b), Shell is the largest gas non-NOC producer in China, with outputs in 2009 amounting to 2.6 Bcm, while other IOCs, including Chevron, Statoil Orient and ConocoPhilips China produced less than 0.1 Bcm.

Unconventional gas provides a better opportunity for IOCs to participate in onshore gas production, as Chinese NOCs often have to rely on the expertise and technology of IOCs, but IOCs need to learn how to establish network and trust with NOCs and the central government (a case study of shale gas is given later in this section). My interview with Shell China in June 2013 highlighted the strategy and mentality of IOCs in running businesses in China (Interview 7). Shell was invited by the central government to participate in E&P in the Changbei gasfield in 2003 because the government wanted to ensure sufficient supplies of gas to reduce Beijing's coal use before the 2008 Olympics. Changbei gasfield is a tight gas reservoir. Although Chinese NOCs had the technology to exploit it, their technology was not advanced enough to produce gas as quickly as needed. Shell has a proven track record in this area and was invited to sign a PSC with CNPC, where Shell controls 49 percent. In the end, Shell delivered the production target it has promised. The senior staff I interviewed shared that this was a landmark victory for Shell because the central government will remember the contribution of Shell ("making the government look good"), and both entities have established trust and connections, which would result in more E&P opportunities in the future. In fact, Shell and PetroChina signed an agreement to jointly develop tight gas deposits in China's Sichuan Province in March 2010. Under a 30-year PSC, the companies will first appraise and then potentially develop tight gas reservoirs across 4,000sq km of the Jinqui block. Although details of the agreement were not included in Shell's press release, Reuters quoted an unnamed source as saying that Shell would be making the "total investment" and would be taking a stake of more than 50 percent in the project, which will be unprecedented if it comes true (Business Monitor 2013a).

This strategic coupling for regional development is evidenced in the area of tight gas. China does not classify tight gas (i.e. gas that is trapped in low permeability reservoirs, such as tight sandstone) as a form of unconventional gas, so it does not enjoy the same preferential policy treatment as CBM and shale gas. But the technological support of IOCs (and OFSs), as in the above case of Shell, has contributed to a "tight gas boom" since 2005, particularly when development accelerated in the Ordos basin. CNPC started exploring developing tight gas in the early 1990s, but production hovered around 1-2 Bcm until the mid-2000s when China applied effective drilling techniques such as horizontal drilling and multistage fracturing brought by experienced IOCs such as Shell, and OFSs such as Anton (see next section). Tight gas outputs surged from 4.8 Bcm in 2006 to 32 Bcm in 2012, i.e. almost a third of China's total domestic gas production, making China the world's second-largest tight gas producer after the United States (Standard Chartered 2013, p.11).

In addition to the technological requirements of developing more challenging gas fields, Chinese NOCs have become more open to IOCs in exchange for future cooperation in regions outside China. My informant from Shell also emphasised that Chinese NOCs are keen to get overseas business in return for allowing international competitors into their home territory. Cooperation with IOCs has proven to be crucial for Chinese NOCs to enter into many unfamiliar host countries and to reduce risks in their investments. Instead of working alone, as in their early days in Africa, Chinese NOCs are now keen to establish strategic partnerships with IOCs. This was particularly the case in 2009 when Chinese NOCs joined with other IOCs to participate in bidding rounds in Iraq. Bidding in partnership diversified the risk for each company in a highly risky and politically unstable country (Jiang & Sinton 2011).

The IOCs and other NOCs have been keen to work with Chinese NOCs because, as industry insiders have pointed out, "the wind is blowing towards the East" (Jiang & Sinton 2011), given the spatial shift is the centre of gravity of energy demand towards to the East. Shell, for example, has found its way to partner with Qatar and China and included both countries to be its infra-firm coordination (see also Bradshaw (2013)). The executive director of Shell, Linda Cook, vividly summarised the strategic complementaries among Qatar, Shell and China: "These agreements underline the partnerships that Shell is building with both suppliers and consumers to help meet the global energy challenge. Qatar is the giant of the LNG sector and China is emerging as a very significant gas market. Linking supply and demand through long-term agreements should be of tremendous benefit to both sides" (Shell 2008).

There is another strategic reason why some forward-looking IOCs want to participate in China's upstream gas sector, which they deem unprofitable. In August 2012, Shell announced plans to invest US$1 billion per year into developing China's shale gas resources, yet the participation in shale gas activities is currently "money burning", according to my Shell informant (Interview 7). My interview with the Vice President of BP China also confirms that "IOCs are not really interested in China's onshore gas E&P, as the resources are few and of low quality" (Interview 24) . But both Shell and BP believe that having a stake in China's upstream gas sector helps them better monitor and evaluate China's oil and gas development on the frontline from upstream to downstream via corporate networking and direct collection of market information. Moreover, it appears that Shell judges that, although China's unconventional gas industry is still in its nascent stage, a forward-looking IOC would want to establish deep and rich networks with the central government and NOCs before the industry takes off.

4.3.2. Oilfield Service Firms

The Economist (2012b) called the OFS firms "the unsung masters of the oil industry", as they are less well-known than IOCs but their capitalisation is no less than many IOCs. For example, Schlumberger's capitalisation reached US$119 billion in 2013 (Table 4.2), larger than some IOCs including Eni ($82 billion), Statoil ($75 billion) and Conoco-Philips ($71 billion). There are three types of OFS firms:(i) those which make and sell expensive kit for use on drilling rigs or the seabed, such as FMC, Camero, National Oilwell Varco; (ii) those which own and lease out drill-rigs, such as Transocean, Seadrill, and Honghua in China; and (iii) those which carry out most of the tasks involved in finding and extracting oil, dominated by Schlumberger, Halliburton, Baker Hughes, and Weatherford International. According to Spears and Associates, the overall OFS market for China is RMB92.2 billion, mainly dominated by the three NOCs and their in-house OFS subsidiaries with 85 percent of the total market share (Platinum Broking 2013). Despite their small market share, some independent domestic OFS, such as Anton Oilfield Services, SPT Energy and Termbrary Petro-king Oilfield, have a niche in high-end and critical services, as technology becomes increasingly specialised for complicated reservoirs. There is also a room for international OFS, such as Schlumberger, Halliburton and Baker Hughes, which now together hold a 5 percent market share in China.

Table 4.2 Size of Selected OFS Firms by Region, 2013

	Market Capitalisation (US$ million)
Hong Kong-Listed	
Anton Oilfield Services	1315
SPT Energy	910
Termbray Petro-king Oilfield	563
China-listed	
LandOcean Energy Services	1543
Kingdream	1131
Gi Technologies Beijing	690
North America-listed	
Schlumberger	118671
Baker Hughes	43047
Weatherford International	24493
RPC lnc	11918
Trican Well Service	1814
Calfrac Well Services	1347
C&J Energy Services	1260

Source: Standard Chartered (2014, p.5)

Domestic and foreign OFS firms wanting to do business in China need to do business with NOCs, especially as sub-contractors of the NOC's in-house OFS firms. These in-house OFS firms were all created after 2007 (Table 4.3) and are the major clients of all private OFS firms in China, both foreign and domestic. In 2011, these in-house OFS firms sub-contracted independent OFS firms accounted for only 19 percent (Standard Chartered 2014, p.16). Demand for OFS in China rose significantly after 2005 when China began extensively developing natural gas reserves in the Tarim, Ordos and Sichuan basins, where companies began drilling more horizontal wells to unlock tight gas deposits.

The share of low-permeability oil and gas reserves climbed to 80 percent by 2012, and the number of horizontal wells drilled after the tight gas boom has risen dramatically since 2006 (Standard Chartered 2014).

Table 4.3 China's NOCs' In-house OFD Firms

Name	Service	Major Markets	Employees	Started
CNPC Chuanqing Drilling Engineering	Exploration seismic surveys, drilling, downhole operations, well testing and perforation, logging, surface construction, overall field development.	Domestic: Sichuan, Changqing, Tarim, Qinghai; Overseas: Turkmenistan, Pakistan, Ecuador, Nigeria, Indonesia	43000	2008
CNPC Xibu Drilling Engineering	Drilling, testing, logging, cementing.	Domestic: Xinjiang, Gansu, Inner Mongolia, Sichuan; Overseas: Kazakhstan, Uzbekistan, Saudi Arabia, Egypt	24000	2007
CNPC Greatwall Drilling	Drilling, drilling fluids, cementing, testing, logging, reservoir evaluation, overall development of heavy oil, CBM and low-permeability reserves.	Domestic: Liaohe, Daqing, Changqing; Overseas: 28 countries including Kazakhstan, Oman, Cuba, Libya, Sudan, Turkmenistan, Iraq and Venezuela	38000	2008
CNPC Bohai Drilling Engineering	Drilling, downhole operations, directional drilling, logging, testing, cementing, tubular services, drilling fluids, oilfield technology research, overall field development.	Domestic: Huabei, Dagang, Tarim, Jidong, Changqing; Overseas: Venezuela, Indonesia, Iraq, Iran	28900	2008
CNPC Daqing Drilling Engineering	Exploration seismic surveys, drilling, testing, logging, cementing, repair.	Domestic: Daqing, Jilin, Xinjiang, Jidong; Overseas: Venezuela, Sudan, Iraq	33000	2008
Sinopec Oilfield Service	Reservoir assessment, exploration surveys, drilling, cementing, testing, logging, stimulation, equipment manufacturing, offshore oilfield development.	Domestic: Shengli, Ordos, Sichuan, Xinjiang, etc.; Overseas: Africa, Asia, Middle East and Americas	140000	2012

Source: Standard Chartered (2014, p.16)

Chinese NOCs have increased their outsourcing to independent OFS firms for three reasons. First, unconventional gas, especially tight gas and shale gas in the future, requires dramatic increases in well drilling per field. As a result, demand outpaced capacity increases at the NOCs' OFS subsidiaries, which had to outsource work to independent OFS firms to meet the aggressive production targets set by the parent companies or the central government. Second, the in-house OFS firms are undergoing corporate reforms, shifting their strategic focus from scale expansion to enhancing efficiency. They need independent OFS firms not only because their capacity is insufficient, but also because of the opportunity to learn from their independent counterparts. The independent OFS firms have higher per-capita productivity due to more efficient staffing arrangements, and their revenue generation on a per-employee basis is double the NOCs' level, making their net margins significantly higher than NOCs' as well (Standard Chartered 2014, p.14). The in-house OFSs, such as Sinopec Oilfield Service, now benchmark themselves against international peers such as Schlumberger and Baker Hughes, and aim at technology-driven higher-end markets, in order to prepare for a planned stock-exchange listing in the near future. Third, the need for advanced techniques like multi-stage fracking have also created opportunities for international (and domestic) OFSs capable of introducing new solutions in China.

There are both domestic and international OFS firms. While the domestic OFS firms, such as Anton, Petro-king and SPT, have already been able to provide services from exploration drilling, field development, well completion and stimulation to production, international OFS firms can participate in China's gas E&P in three ways. First, key international OFS firms, such as Schlumberger, had been working closely for the Chinese government in the 1980s, before the establishment of Chinese NOCs, let alone other OFS firms. Their track records have won the trust of the government and the NOCs, who are willing to outsource their projects to them, especially those requiring most advanced technologies (Interview 8). Second, international OFS firms can get into Chinese business through capital investment in domestic OFS firms. For example, Schlumberger, the world's largest oilfield services company (in terms of market capitalisation), acquired a 20.1% stake in Anton Oil in July 2012. Baker Hughes has also signed a cooperation agreement with Honghua Group to develop unconventional natural gas in China (Business Monitor 2013b). Third, China is reported to possess enormous shale gas endowment but the difficulty of developing it is even higher than the US shale plays, requiring the most advanced technology and innovation provided by the international OFS giants. My informant from Schlumberger China stated that, for example, the Sichuan shale basin is not only deeper than the US shale plays, but is under enormous tectonic pressure. This senior staff member of Schlumberger China claimed that the conventional method of hydraulic fracturing used widely in the US is not powerful enough to fracture the Sichuan shale plays, and he boldly believed that not one OFS firm anywhere in the world could provide a commercial solution. He went on to say that, unlike integrated energy firms, Schlumberger is a specialist only in the E&P; together with the financial ability and reputation to attract the world's top engineers and scientists, they can come up with technology and solution unthinkable and unmatched by domestic OFS firms or the NOCs' in-house OFS firms. And most of the technologies the domestic OFS firms now rely on are those the international OFS firms, such as Schlumberger, adopted in the 1980s or before, after the expiry of their related patents, according to him. Although the informant did not specify what technology their company can uniquely offer to the Chinese NOCs, this informant claimed that they had finally come up with an idea to fracture the Sichuan basin but they were still working on how to commercialise it. In addition to Schlumberger, there are other international OFS firms interested in the Chinese market. For example, GE Oil & Gas, the OFS arm of US conglomerate GE, is looking into ways of cutting the amount of water needed for E&P - targeting the issue of China's water scarcity. Baker Hughes has already teamed up with Sinopec and PetroChina to drill some of the country's first shale gas appraisal wells in early 2012. Halliburton is also working on shale gas wells in Sichuan and Chongqing (Business Monitor 2013b).

The case study of shale gas in the next section will show that the entry of non-oil/gas producing companies, such as coal producers and property developers, into the shale gas industry will further increase the need to outsource oil field services to international firms with advanced technology.

4.3.3. Case Study: Shale Gas as An Opportunity for Strategic Coupling

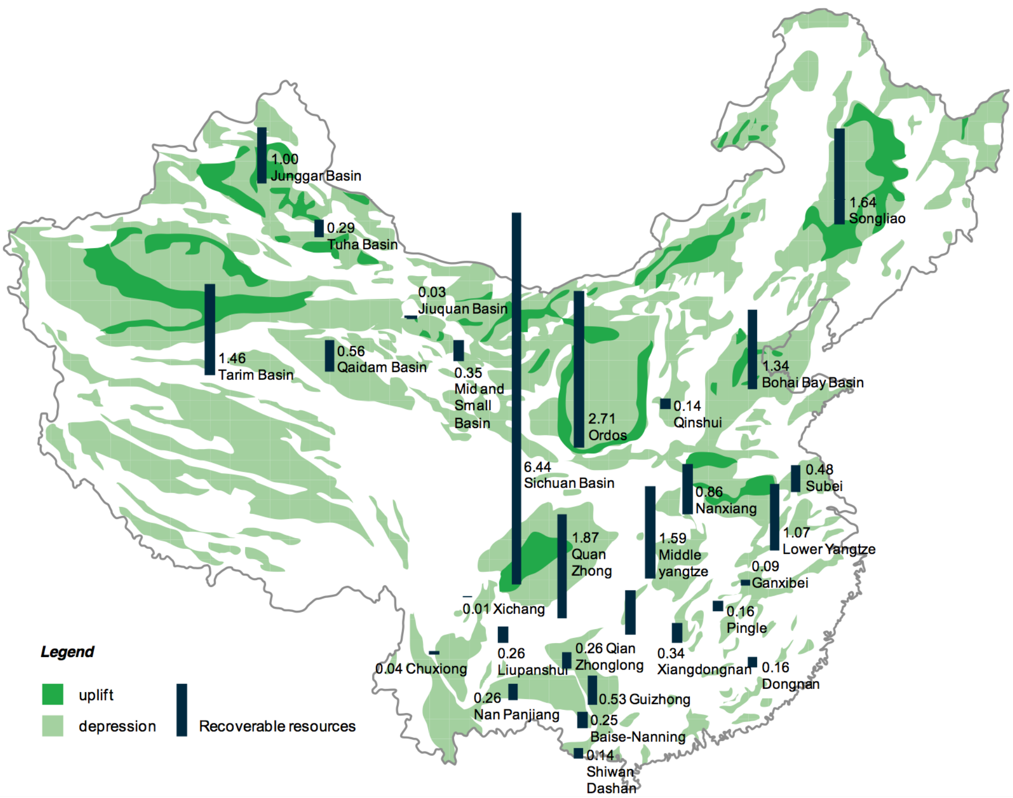
China has the world's most abundant technically recoverable shale gas resource. The US EIA published its first international assessment of shale gas resources in 2011 and estimated that China's recoverable shale gas endowment amounted to 36.1 Tcm, which was 68 percent larger than the US (Table 4.4). In 2012, the MLR released China's official estimate of 25.08 Tcm, a figure much smaller than that estimated by EIA but, even so with reserves still 32% above those of the US, China's status as the world's most significant shale gas resource remains unchallenged. The most obvious difference between the two estimates is that the EIA excluded the Ordos basin from the sampling. The MLR explained that it was because the "EIA lacks the data and experience to assess Ordos' Lacustrian reserves" (Standard Chartered 2013, p.30), although it is unclear why the EIA's exclusion of a large basin has resulted in a larger estimate. Based on current geological knowledge, Sichuan basin is sitting on the largest endowment of shale gas (Figure 4.10) (Standard Chartered 2013, p.31).

Table 4.4 Estimates of China's Technically Recoverable Shale Gas Resources

Institution	**Estimate**	**Year**
Ministry of Land and Resources (MLR)	25.08 Tcm	2012
Energy Information Administration (EIA)	36.1 Tcm	2011
Research Institute of Petroleum Exploration and Development	10-20 Tcm	2009
CNPC	11.4 Tcm	2009
China University of Geosciences (Beijing)	26 Tcm	2008

Source: Zeng et al. (2014)

Figure 4.10 Technically Recoverable Shale Gas Resources by Basin (Tcm)



Source: Standard Chartered (2013, p.3) based on MLR estimate

The official discourse about China's energy resource profile has long been "abundant with coal, poor in oil and lack of gas" (duomei pinyou shaoqi), but recognition of the country's very rich unconventional gas resource means such a discourse needs to be revised. To facilitate and guide the national development of shale gas industry, the central government issued "Shale Gas 12th Five-year Plan" (2011-2015) and requested China's shale gas output reach 6.5 Bcm by 2015 and 60-100 Bcm by 2020. However, my ground checks in Beijing with the key NOCs and IOCs confirmed the growing consensus reported in the media that the 2015 production target will likely fall short (Interview 9). The internal production targets of CNPC, Sinopec and Yanchang are in fact 1.5 Bcm, 1 Bcm and 0.5 Bcm, respectively (Standard Chartered 2013, p.44). My informant from CNPC's extraction divison expressed some very negative opinions on shale gas in the short term. He stated that CNPC is currently uninterested in developing shale gas, as long as the regulated wholesale gas prices that are set by the NDRC are lower than production costs. According to his ballpark figures, the 2013 average national wholesale price is around 1 RMB per cubic metre (about US$0.16), while the estimated production costs of shale gas in Sichuan basin (already the easiest basin) are above 3 RMB per cubic metre.

The NOCs are not interested in developing their shale basins now, and so major E&P activities are concentrated on the 23% of shale gas reserves that are not currently allocated. The central government held the first shale gas auction in June 2012 and offered four blocks near Chongqing in southwestern China. It was conducted closed-door and by invitation, and received nine bids from (1) CNPC, (2) Sinopec, (3) China United Coalbed Methane (CUCBM), (4) Shaanxi Yanchang and (5) Henan Provincial Coal Seam Gas Development and Utilization (Henan Provincial Coal). Sinopec and Henan Provincial Coal won the three-year exploration rights of the Nanchuan (Sinopec) and Xiushan (Henan Provincial Coal) blocks, because they proposed the highest number of wells drilled with the largest spending pledge. The other two blocks failed to attract sufficient interest from the companies and were not sold.

The central government authorities, led by the MLR, regard an open market as having been key to the success of shale in the US. The MLR has tried to introduce increased competition by auctioning blocks – especially through the second round of bidding, which was open to all companies. The second round was held in September 2012. All Chinese companies and Chinese-controlled foreign JVs with a registered capital of not less than RMB 300 million were eligible to bid if they had the oil/gas E&P qualifications, or a partnership with companies with such qualifications. The scale of blocks was also much larger, with 20 up for sale in eight provinces and regions (Chongqing, Guizhou, Hubei, Hunan, Jiangxi, Zhejiang, Anhui and Henan). The second round attracted interest from 91 companies, and 83 eventually submitted bids. Sixteen companies won the exploration rights for 19 blocks and one block was not sold due to a lack of interest. As in the first bid, rights to explore were valid for three years, but the new terms required successful bidders to spend at least RMB 30,000 per sq km annually, and specified that the number of exploration wells drilled must exceed two for each 500 sq km on average.

Among these sixteen successful bidders in the second round, 50 percent were local SOE, 37 percent central SOE and 13 percent private companies (Table 4.5). What is significant is that none of these sixteen firms had drilled for shale before. A research firm, Sanford C. Bernstein, commented that "[w]hile China remains too dependent on PetroChina and Sinopec for the development of its shale industry, opening up acreage to provincial governments and companies with no experience in oil and gas (coal, power) can hardly be seen as a positive" (China Economic Review 2013). While the NOCs and even the IOCs I interviewed (i.e. Shell and BP in this case) did not express sincere interest in shale gas at present — my CNPC informant stated that their entry to the first round is largely because of political obligation — it invites a question of why these non-oil/gas firms are interested in a uncertain industry, and why they bid when the MLR did not offer them much seismic information about the blocks (China Economic Review 2013). My CNPC informant judged that these firms were either ill-informed or mis-led, or seeking to benefit by selling the exploration right to a third party or by using the "shale gas" concept to raise their share prices.

Table 4.5 Details of the Successful Bidders in the Second Shale Gas Auction

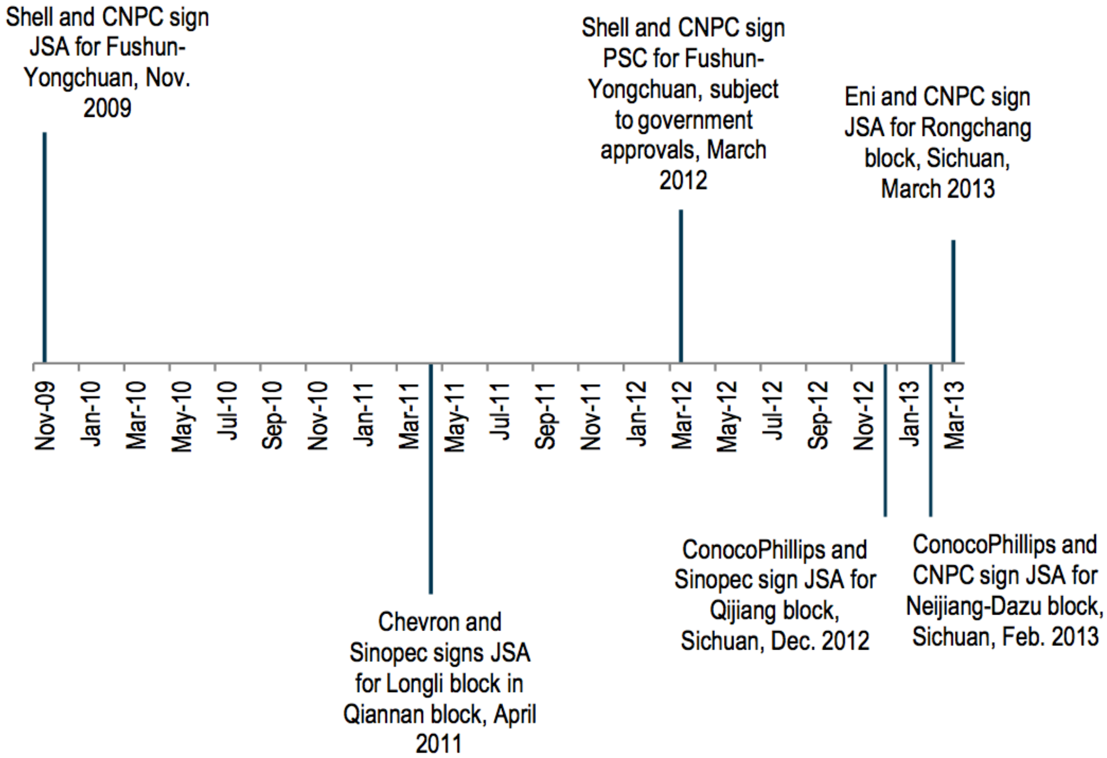
Block	Size (sq km)	Location	Successful bidder	Type of company	three years (RMB mn)
Suiyang	1,024.53	Guizhou	Huadian Coal Industry Group	Central govt.	92.21
Fenggang-1	1,053.37	Guizhou	China Coal Geology Engineering	Central govt.	94.80
Fenggang-2	1,030.40	Guizhou	Huaying Shanxi Energy Investment	Private (600167.CH)	92.74
Fenggang-3	1,167.49	Guizhou	Beijing Taitan Tongyuan Natural Gas Technology	Private	105.07
Cengong	914.63	Guizhou	Tongchuan City Energy Investment	Local govt.	82.32
Qianjiang	1,272.40	Chongqing	Chongqing City Energy Investment	Local govt.	114.52
Youyang East	1,002.09	Chongqing	Chongqing Mineral Resources Development	Local govt.	90.19
Chengkou	1,020.95	Chongqing	State Development and Investment	Central govt.	91.89
Longshan	878.00	Hunan	Hunan Huasheng Energy Investment	Local govt.	79.02
Baojing	1,189.72	Hunan	Shenhua Geological Exploration	Central govt.	107.07
Huangheng	400.43	Hunan	China Huadian Engineering	Central govt.	36.04
Sangzhi	760.36	Hunan	China Coal Geology Engineering	Central govt.	68.43
Yongshun	982.23	Hunan	Hunan Provincial Shale Gas Development	Local govt.	88.40
Laifeng-Xianfeng	369.23	Hubei	Hudian Hubei Power Generation	Central govt.	33.23
Hefeng	2,306.71	Hubei	Hudian Hubei Power Generation	Central govt.	207.60
Xiuwu Basin	598.28	Jiangxi	Jiangxi Natural Gas Holdings	Local govt.	53.85
Lin'an	580.09	Zhejiang	Anhui Provincial Energy Investment	Local govt.	52.21
Wenxian	1,377.91	Henan	Henan Yukuang Geological Exploration Investment	Local govt.	124.01
Zhongmou	1,395.99	Henan	Henan Yukuang Geological Exploration Investment	Local govt.	125.64
Total	**19,324.81**				**1,739.23**

Source: Standard Chartered (2013)

Although NOCs paint a rather grin picture of China's shale gas development in the near future, no firm doubts the significance of shale gas to China's gas transition over the longer term, especially after 2020. Given the technological difficulty of shale gas development, both NOCs and non-experienced bidders need to rely on the advanced technology of the IOCs and international OFS firms. Recognising the need for international cooperation, the central government published the Guidance Catalogue for Foreign Industrial Investment (2011 revision), which defined regulations for foreign cooperation and joint ventures for shale gas exploration and development (Zeng et al. 2014). In other words, the nascent shale gas industry provides a window of opportunity for a strategic coupling between IOCs and China's regional gas assets and institutions.

As noted before, IOCs are currently not allowed to directly enter the upstream E&P but must form an alliance with an NOC, mainly through PSCs. It means that IOCs carry out the risky exploration at the initial stage and once there is commercial output the NOCs have the right to take 51 percent. Recent examples include the Ministry of Commerce's March 2013 approval of the production sharing contract (PSC) between Shell and CNPC in the Fushun-Yongchuan block in Sichuan, which was the first shale PSC in China and a key milestone for foreign investors seeking a foothold in China's unconventional gas industry (Figure 4.11). IOCs currently working with NOCs in the shale gas sector include Shell, BP, Chevron, ConocoPhilips, ENI and Statoil, and most take place in Sichuan (Table 4.6).

Figure 4.11 Timeline of IOC-NOC Cooperation in Shale E&P



Source: Standard Chartered (2013)

Table 4.6 Major IOC Involvements in China's Shale Gas Exploration

Date	IOC	NOC	Activity	Basin	Area (Km2)
Oct-07	Newfield	CNPC	Joint Study	Sichuan	
May-09	Statoil	CNPC	Joint Study	Sichuan	2000
Nov-09	Shell	CNPC	Joint Assessment	Sichuan	3000
Jan-10	BP	Sinopec	Joint Assessment	Jiangsu	
3Q 2010	ConocoPhilips	CNPC		Sichuan	2000
4Q 2010	Chevron	Sinopec	Exploration	Guizhou	
2010	Shell	CNPC	Exploration	Sichuan	
Jul-11	ExxonMobil	Sinopec	Joint Study	Sichuan	3644
Jul-11	ENI	Sinopec	MOU		
Mar-12	Shell	CNPC	Joint Study	Sichuan	3500
Apr-11	Chevron	Sinopec	Joint Study	Qiannan	
Dec-12	ConocoPhilips	Sinopec	Joint Study	Sichuan	3917
Feb-13	ConocoPhilips	CNPC	Joint Study	Sichuan	2023

Sources: Gao (2012, p.18), Business Monitor (2014, p.18)

4.4. Gas Imports

4.4.1. Overview

When a country's gas demand grows faster than its production, the gap needs to be filled with imports. The shale gas boom in the US has dramatically increased domestic gas outputs and is likely to turn the country from a gas importer to a gas exporter. It remains to be seen whether China's unconventional gas development will become fully commercial after 2020 and what the implications will be for China's gas imports. Statistically, the international gas trade of China began in 1997 when China exported gas produced from the offshore Yacheng gas-field in the South China Sea to Hong Kong (Table 4.7) (although Hong Kong became a special administrative region of China in July 1997, China's official statistics conventionally consider Hong Kong as a foreign entity). In a real sense, China has participated in international gas trade only since 2006, when its Guangdong Dapeng LNG receiving terminal (the country's first) was commissioned (Photo 4.1). As a consequence, China became a net gas importer in 2007. Since then China's gas imports have climbed rapidly, from less than 1 Bcm in 2006 to 42.7 Bcm in 2012, of which 53 percent were pipeline gas from Turkmenistan, and the remaining 47 percent LNG. In 2012 China surpassed the UK and Spain to become the third largest LNG importer after Japan and Korea (Chen 2013), and its import dependency (i.e. percentage of net imports over domestic consumption) of gas climbed rapidly from 2 percent in 2007 to 21 percent in 2011. The analysis below on China's gas imports via pipeline and LNG finds that a consideration of geopolitical vulnerability, either perceived or actual, by Chinese policy-makers has significantly shaped the selection of import routes and means.

Table 4.7 China's Gas Balance, 1990-2012 (Bcm)

	Production	Consumption	Import			Export	Net Import
				Pipeline	*LNG*		
1990	15.3	15.3					
1991	15.5	15.9					
1992	15.8	15.9					
1993	16.8	16.8					
1994	17.6	17.3					
1995	18.0	17.7					
1996	20.1	18.6					
1997	22.7	19.6				0.0	0.0
1998	23.3	20.3				0.0	0.0
1999	25.2	21.5				3.4	-3.4
2000	27.2	24.5				3.1	-3.1
2001	30.3	27.4				3.0	-3.0
2002	32.7	29.2				3.2	-3.2
2003	35.0	33.9				1.9	-1.9
2004	41.5	39.7				2.4	-2.4
2005	50.9	46.8				3.0	-3.0
2006	58.6	56.1	1.0		*1.0*	2.9	-1.9
2007	69.2	70.5	4.0		*4.0*	2.6	1.4
2008	80.3	81.3	4.6		*4.6*	3.2	1.4
2009	85.3	89.5	7.6		*7.6*	3.2	4.4
2010	94.8	106.9	16.5	*3.5*	*13.0*	4.0	12.4
2011	102.7	130.5	31.2	*15.0*	*16.4*	3.2	28.0
2012	106.7	132.8	42.7	*22.8*	*19.9*		

Source: CEIC (2014)

Photo 4.1 Guangdong Dapeng LNG Receiving Terminal Under Construction

Source: Taken by the Author in early 2006

4.4.2. Pipeline

In Pacific Asia, China is the only country that imports gas through both LNG and pipeline. Currently there are two trans-border gas pipelines in operation, including Central Asia-China Gas Pipelines (operated in 2009) and Myanmar-China Oil and Gas Pipelines (operated in 2013) (Figure 4.12). The proximity to gas-rich neighbouring countries and the diversification of "perceived vulnerability" away from dependence on the Strait of Malacca are the driving forces behind pipeline projects. The official "Malacca Dilemma" narrative provides a useful agent to justify the construction of overland pipelines, both oil and gas. According to then President Hu Jintao and many analysts, 70-80 percent of the oil from Africa and the Middle East "must pass through" the Malacca Strait, wedged between Indonesia and Malaysia. Many Chinese leaders believe that this Strait is a chokepoint, exposing China to possible oil supply disruptions caused by a blockade by the U.S. Navy in response to a conflict over Taiwan, or pirate attacks. The fact that East Asia has seen seven naval blockades in the twentieth century, and that lessons were learned from the 1982 Falklands War known as a ''classic example of modern limited blockade,'' both intensify such fears. Pipelines help calm these fears as Chinese leaders believe that overland pipelines can reduce reliance on the Strait of Malacca (Leung 2011).

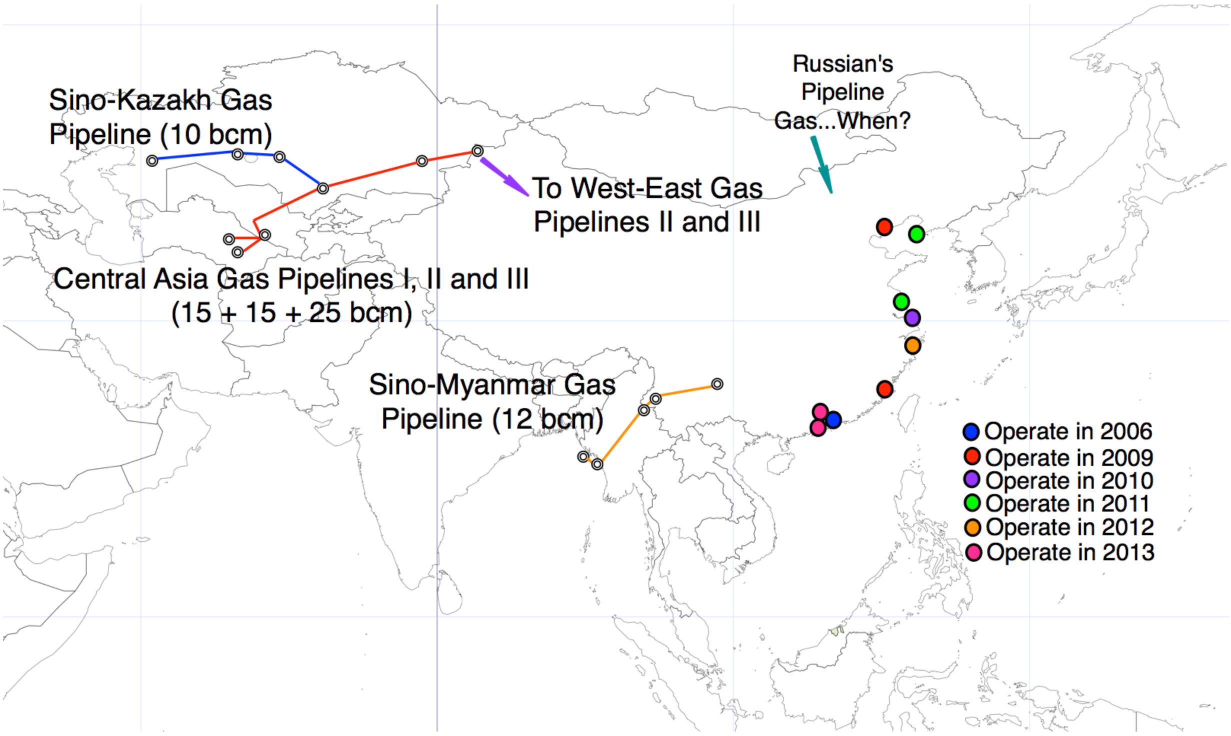
In reality, the contribution of these pipelines to China's energy security is smaller than many assume. First, the so-called Malacca Dilemma has been commonly exaggerated. When faced with non-military disruptions in the Strait of Malacca, such as pirate attacks or crashes, oil tankers towards China can always be diverted through alternative passages, e.g., the Sunda and Lombok straits at an additional cost of as little as one or two dollars per barrel. Second, the proposed alternative import route via pipeline from Myanmar is already politically unstable. My CNPC informant was surprisingly honest in saying that CNPC exaggerated the risk of the "Malacca Dilemma" and the benefit of Myanmar-China Oil and Pipelines in exchange for political support from central government to allow CNPC to "invade" Sinopec's traditional sphere of influence in South China. The central government supported CNPC's position either because they really bought the story of increased import security, or because they thought CNPS' project could strengthen Myanmar-China diplomatic ties and fend off the geopolitical influence of India (Interview 4; Interview 10). He was frank that many CNPC colleagues know Myanmar is political unstable and US influence is taking root there: the pipeline might be a new source of vulnerability to China's energy security, but it justifies China's presence and increases bargaining power (Interview 4). The term "pipeline diplomacy" is sometimes used to describe the close linkage of pipelines and geopolitical relations: however it may be taken to mean either "diplomacy for pipelines" or "pipelines for diplomacy", and the Myanmar-China pipelines seems to fit the latter's definition more.

The Central Asia-China Gas Pipeline was also partly geopolitically driven, and largely associated with China's strategy to increase their bargaining power against Russia. Russia proved to be an unreliable energy ally after it suddenly abandoned the Angarsk-Daqing pipeline and replaced it with the East Siberia–Pacific Ocean (ESPO) pipeline, reflecting Russia's unwillingness to over-depend on the Chinese market (Downs 2010, Paik 2012). To counter-balance Russia, China initiated the Sino-Kazakh Oil Pipeline and Central Asia-China Gas Pipeline. The form of implementation of this gas pipeline was also affected by Chinese concerns over Russia. To avoid provoking Russia's anger by pursuing gas imports from Turkmenistan through a mega pipeline, China adopted the equity gas model by choosing to build the pipeline and develop a new gas field by itself. This model protects China from attacks from Russia or the European Union (Paik 2012). Moreover, according to an informant from CNPC's Sino-Russia Cooperation and Project Department (Interview 11), CNPC chose to build two 1067mm diameter pipelines (i.e. phases I and II) in parallel instead of the original plan to build a 1422 diameter pipeline to avoid Russia's participation. This decision was because China lacked the technology to produce the higher-capacity pipe and would need to rely on Russia's technology to manufacture it, something China sought to avoid.

Discussions between China and Russia have been ongoing for decades, focusing on the possibility of a 68 Bcm deal via a western corridor (supplied with gas from West Siberia) and an eastern corridor (supplied with gas from the Russian Far East). The primary reason for the stalled progress is the price China is willing pay for Russian gas (Bradshaw 2013b). Talking to the Chinese and Russians, one can find two different versions of the story: whereas the Chinese would say that they do not need any additonal pipeline gas before 2015, the Russians insist that the Chinese are desperate to have it (China Economic Review 2011). However, while Russia has been playing hard to get, China has secured pipeline gas from Central Asia and Myanmar, meaning that it does not need more gas import capacity in the west. Considering the rapid development of LNG imports in the east, and the potential of unconventional gas supplies in the future, the market opportunity for Russian pipeline gas is now confined to the eastern corridor and is closing quickly (Bradshaw 2013b). In May 2014, Russia and China have finally agreed to a

$400 billion deal for the delivery of 38 Bcm of natural gas to China via the eastern corridor starting in 2018.

Figure 4.12 China's Gas Import Infrastructure 2013



Source: The Author

4.4.3. LNG

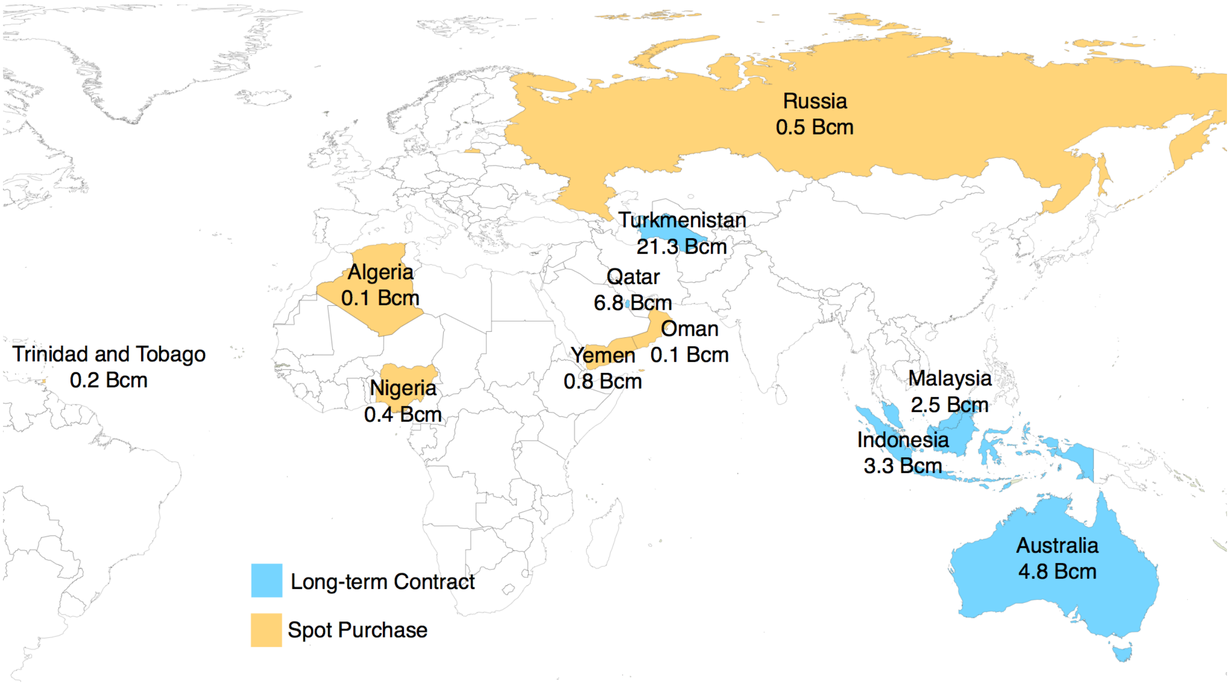
Infrastructure build-up is essential to the increasing demand for LNG imports. Since the launch of Guangdong Dapeng LNG terminal, eight additional regasification terminals have begun operation, with a total receiving capacity of 40.6 Bcm per year by the end of 2013 (Table 4.8) (Figure 4.13). Four new terminals and one Phase II expansion project are now under construction. By 2015, this will add up to a total receiving capacity of 62.1 Bcm per year. Chinese LNG buyers, i.e. CNOOC, CNPC and Sinopec, have signed fifteen long-term LNG contracts either directly with the consortium operating a specific source of LNG supply (e.g. Australian NWS) or in the form of portfolios (i.e. specific gas sources may change over time) (Table 4.9). Unlike the Atlantic Basin, Asian LNG deals are dominated by long-term contracts, based on considerations of security of supply for the buyers and security of demand for the producers. Before the construction of LNG value chains (from LNG plants in supplying countries to regasification terminals in receiving countries), the buyer and seller usually agree on a long-term purchase and sales contract, as a way of managing supply risks and financing their investments. In China's case, the length of these contracts are 15-25 years (except in the case of the contract with GDF-Suez). Prices are oil-indexed, with varying slopes in the pricing formula (Stern 2012). Overall pricing displays an upward movement over time: all new cargoes coming on board from 2015 onwards will have the price level of approximately $15/MMBtu or more (given an oil price of $100/bbl) (Chen 2013).

Table 4.8 China's LNG Receiving Terminals

Project	**Year in Operation**	**Capacity (Bcm/y)**
Guangdong Dapeng	2006	5.2
Fujian Putian	2009	3.6
Shanghai	2010	4.1
Jiangsu Rudong	2011	4.9
Zhejiang Dalian	2011	4.2
Zhejiang Ningbo	2012	4.2
Guangdong Dongguan	2013	4.7
Guangdong Zhuhai	2013	4.9
Hebei Caofeidian	2013	4.8
Shandong Qingdao	2014	4.1
Hainan Yangpu	2014	4.2
Shenzhen	2015	5.6
Guangxi Beihai	2015	4.2
Fujian Putian II	2015	3.4
Total		62.1

Source: Chen (2013, p.33)

Figure 4.13 Sources of China's Gas Imports



Source: Data from BP (2013)

Table 4.9 Chinese Long-term LNG Contracts

Seller	Buyer	Import	Volume (Bcm)	First Arrival	Length (Year)	Oil-indexed Price (Slope)
Australia NWS Consortium	CNOOC	Dapeng	4.55	2006	25	5.25%
Indonesia Tanguhh LNG	CNOOC	Fujian	3.64	2009	25	7%
Malaysia LNG TIGA	CNOOC	Shanghai	4.2	2010	25	15-16%
QatarGas II	CNOOC	Zhejiang	2.8	2009	25	15-16%
Total Portfolio	CNOOC	?	1	2010	15	
QatarGas IV	CNPC	Jiangsu	4.2	2011	25	
QatarGas III	CNOOC	Ningbo	4.2	2013	?	
GDF-Suez	CNOOC	Fujian/Shenzhen	3.6	2013	4	
Australia-Queensland/BG	CNOOC	Fujian/Zhuhai	5	2014	20	14-15%
BG Porfolio	CNOOC	?	7	2015	20	
Australia-Gorgon/ExxonMobil	CNPC	Shenzhen	3.15	2014	20	14-15%
PNG LNG/ExxonMobil	Sinopec	Qingdao	2.8	2014	20	14-15%
Australia-Gordon/Shell	CNPC	Jiangsu/Dalian	2.8	2015	20	14-15%
AP LNG/ ConocoPhilip/ Origin	CNPC	Behihai	10.6	2015	20	14-15%
Australia-Icon	Sinopec	Shantou	2.8	2016	20	

Source: Chen (2013, p.35)

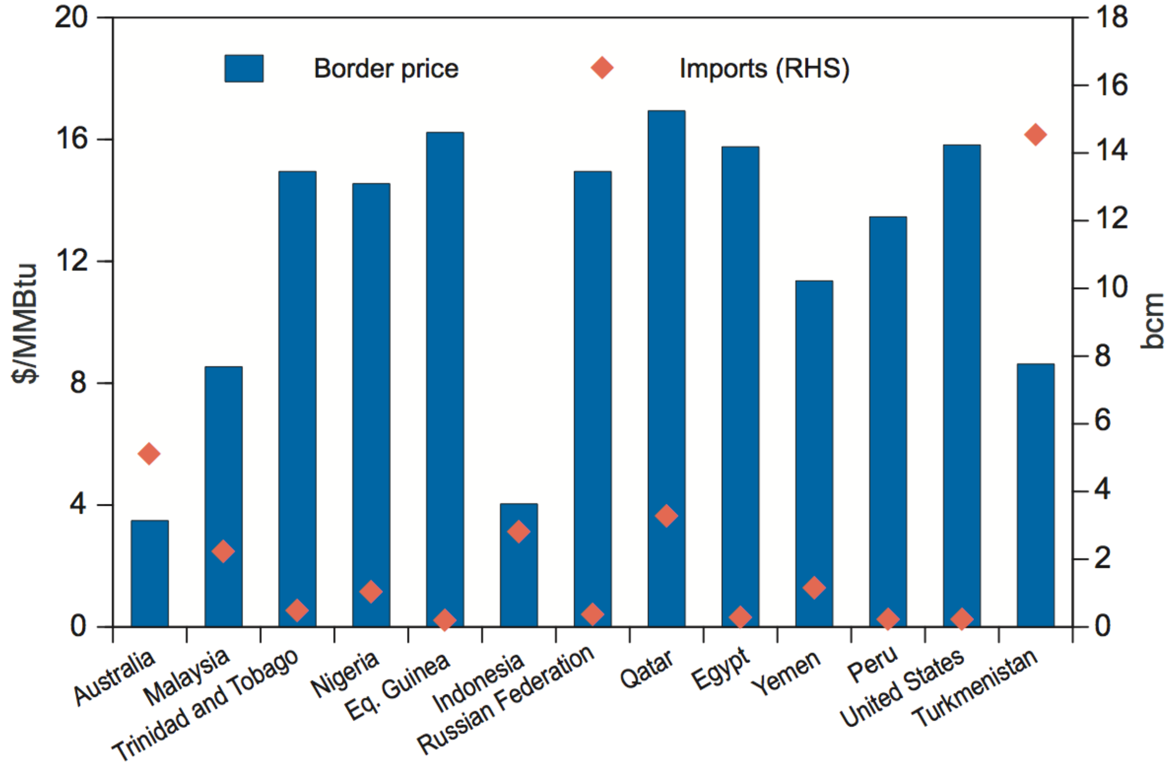
In 2012, China imported 19.9 Bcm of LNG, most of which was based on long-term sales contracts and a small proportion coming from short-term and spot purchases. Australia, Qatar and Indonesia are the three main suppliers with long-term contracts, providing base-load supplies. Spot market purchases from Russia, Africa, the Middle East, South America and West Africa added up to 1.6 Bcm (Figure 4.13). The share of spot market and short-term purchases in the global LNG supply rose rapidly in the early 2010s, and it accounted for over 25 percent of the internationally traded LNG market in 2011

(Chen 2013, p.36). This is because the Fukushima accident created new gas demand in Asia-Pacific, while the collapse of the US LNG import market has left more LNG available for other regions. The reason for China to engage in spot purchases is to balance seasonal demand for gas that is highly volatile. For example, Beijing's peak consumption levels are 10 times that of its trough levels. At the same time China, like other countries in Asia lacks sufficient storage facilities (the current Chinese working gas storage is 1.7 percent of consumption volumes, compared to the world average of 12 percent (Chen 2013, p.36) and this general situation is particularly acute in the demand centre of coastal China, where there are hardly any natural storage facilities for gas (salt caverns or depleted reservoirs). Therefore, it is often the case that China and other Asian countries compete for a limited number of LNG cargoes during the winter months in order to meet high demand. In this case, China (and other Asian countries) need to pay a lot more in order to secure and "lock down" supplies, as suppliers such as Qatar can easily and quickly switch between buyers.

The diversification of LNG sources calls for concerns about fuel cost and security of supplies. Australia signed the initial sale and purchase deal with China in the early 2000s, when international oil prices were low, at a very attractive price of below \$5/MMBtu. The price has been so low that the supplier, Australia NWS Consortium, has suffered losses alarmingly because their operation costs (from salary to construction costs) have risen dramatically. During my fieldwork, I had a chance to meet with the Chinese director of the Australia NWS Consortium, which only set up their office in Beijing in 2013, about a decade after the contract signed. The informant explained that they set up the office suddenly because they wanted to lobby the NDRC and NEA to re-negotiate LNG prices. To do so they felt that sending representatives to Beijing twice a year proved insufficient to maintain personnel and corporate networks with the government and NOCs (Interview 12). The days of cheap LNG have passed, as the expensive long-term contracts (i.e. the ones with Qatar) have pushed up the price. Spot market and short-term purchases are also expensive cargoes, but their volumes are small and so the associated price risks are more tolerable (Figure 4.14).

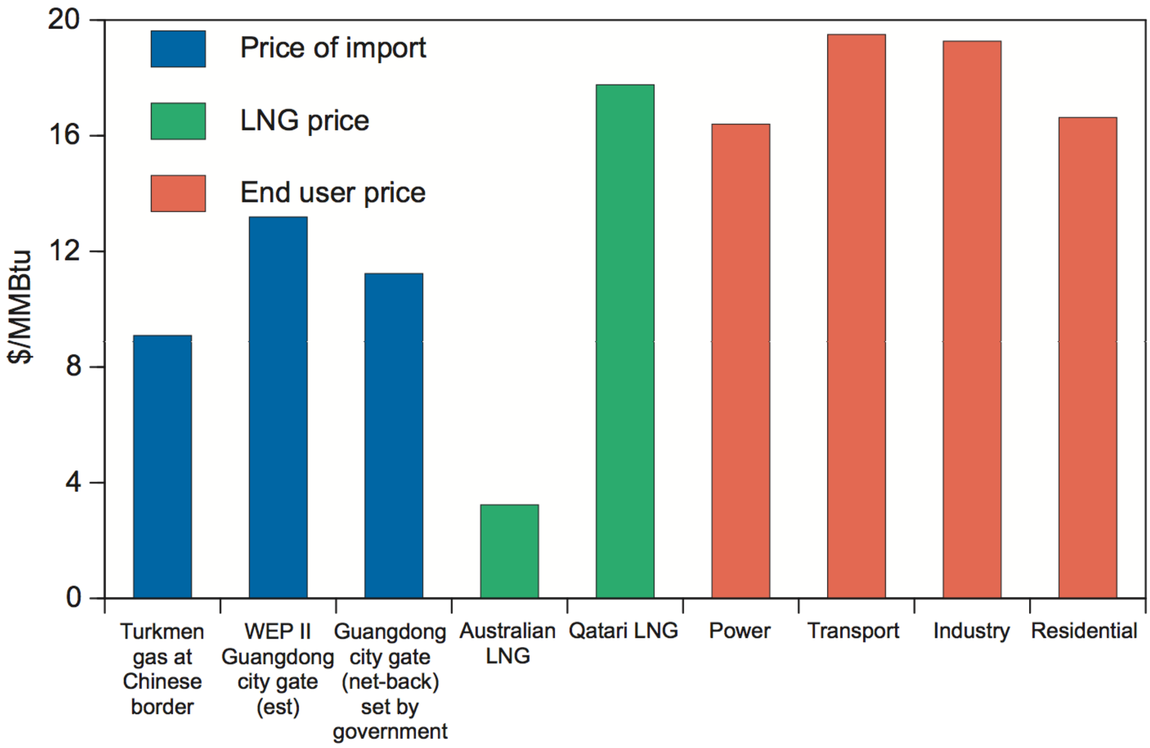
The entry of expensive Qatar LNG and Turkmen pipeline gas to China's gas supply portfolio increases pressure for pricing reforms in a way that additional fuel costs can be passed on to consumers. End-user prices of gas vary widely geographically in China. But the Qatari LNG price is higher than end-user prices in the power and residential sectors even in Guangdong, a province that has the highest gas prices (Figure 4.15). This means that sales of Qatari LNG to most sectors in most regions in China are loss making. The growing proportion of gas imports that almost guarantee losses has discouraged NOCs from producing domestic gas and pressurised the state to accelerate pricing reform. Chapter 5 explains how the NOCs have been developing LNG vehicle markets as a self-help measure, given that gas that is sold in the form of LNG is not regulated by the state.

Figure 4.14 China's Gas Import Prices, 2011



Source: Chen (2012, p.335)

Figure 4.15 Gas Prices in Guangdong, 2011



Source: Chen (2012, p.331)

Furthermore, China's growing gas import dependency is spurring debate over whether the country's security of gas supplies is falling. There are many levels to approach this problem and it cannot be comprehensively addressed here. However a number of issues may be highlighted with the specific goal of enabling the GPN approach to address the charge that it often neglects geopolitical context, as criticised by Glassman (2011) and Levy (2008). In terms of physical proximity, China's growing dependence on gas sources outside Asia can be seen as reducing gas supply security. But one could argue that physical proximity is not always a good indicator. For example, although Turkmenistan is relatively close to China's borders, the pipeline from Turkmenistan to China must transit Uzbekistan and Kazakhstan, and their political stability is questionable. My informant, a risk manager from CNPC, admitted that smuggling and stealing gas from the pipeline traversing Turkmenistan, Uzbekistan and Kazakhstan are evidenced and serious (sometimes at the government level), although the Chinese government chooses to mute it for diplomatic reasons (Interview 5). If one adopts the World Bank's World Governance Indicator (WGI) for Political Stability and Absence of Violence (Kaufmann et al. 2014), Uzbekistan and Kazakhstan in 2012 had WGI Political Stability scores below zero on a scale of -2.5 to 2.5 (the lower, the less stable). Analysts equating energy security with level of diversification often overlook the fact that diversification can actually worsen energy security if the proportion of gas sources in less stable regions increases. If one calculates the weighted

WGI index based on the supplying countries and their respective volumes, the figure declines from 0.92 in 2006 to 0.35 in 2012 on a scale of -2.5 to 2.5, meaning that China's external gas security has fallen. However, these indicators are too a-spatial and abstract, as they do not tell us much about the forms and sub-national distribution of "political instability" and their impacts on gas exports to China. Indeed, it has recently been suggested that "virtually all the countries from which China receives gas are essentially resource states that would not be able to exert much political and economic leverage over China" (Haas 2014). The same commentator further argues that, geopolitically, the future of US LNG might not be very attractive to China, as China prefers overland pipelines to LNG and believes that "relying on the United States for gas supplies would further reduce its already limited leverage [against the US]" (Haas 2014).

4.5. Conclusion

This chapter has examined the actors and institutions surrounding China's acquisition of gas sources. It illustrates how the extractive sector, unlike manufacturing and services, depends not only on social production but also natural production. The spatial dependence of extraction on natural resources highlights issues of finding and accessing these resources. Chinese NOCs benefit from spatial monopoly rents as they have inherited virtually all conventional gas resources (including tight gas in China's context) from the central government in the 1980s when the NOCs were established. They have become a resource manager for the state and exclusive producer of China's gas resources.

The chapter has also shown how China's gas production was not significant before the official promotion of gas consumption in the late 1990s. This led to regional transmission pipeline expansion, liberalisation of the city gas sector, a gradual increase in gas prices, and national natural gas consumption policies that will be discussed in Chapters 5 and 6. This development confirms my argument that the extractive sector is significantly affected by technical, organisational, institutional and social changes in the non-extractive parts of the gas commodity chain. Any part of a gas supply chain, therefore, can only understood relationally. This point is well illustrated via the case of CBM that highlights the implications of resource access for overall gas production.

The chapter found that opportunities for strategic coupling are low in the upstream sector, but China's abundant unconventional gas provides IOCs and international OFS firms better opportunities for cooperation with Chinese NOCs. This is because shale gas is officially listed separately to mitigate the NOCs' monopoly, is technologically demanding, and requires higher numbers of wells be drilled which has outpaced the in-house OFS capacity of NOCs. The case study of shale gas has also highlighted the entry of in-experienced, non-gas players to China's shale gas extraction, and over time these firms will likely invite independent OFS firms (either domestic or international) to help.

Moreover, since energy (including gas) is regarded as a strategic commodity, geopolitics plays an important role when China increasingly needs to import gas from foreign sources, which arouses official concerns about the external vulnerability of gas supplies and diplomatic dependence. Evidence suggests that such concerns have been factored into the design of the Central Asia-China Gas Pipeline to lower Russian involvement, and in the idea of the Myanmar-China Gas Pipeline, which provides limited gas supplies but helps diversify the route of China's gas imports away from the Malacca Strait, and increases China's diplomatic presence in Myanmar.

In terms of LNG imports, three trends can be summarised and they affect, and are affected by, other parts of the gas supply chain as well. First, average LNG prices in China are on the increase, as more recent contracts are priced higher, reflecting growing competition for LNG in the Asia Pacific region. The "take-or-pay" clauses of highly priced LNG and pipeline supply contracts mean that NOCs have to buy contracted volumes of gas at contracted prices, regardless of local pricing and domestic production. Some analysts claim that the slowing growth rate of China's gas outputs – 5 per cent in 2012 vis-a-vis 11.8 per cent on average during 2007-2011 – results from the fact that "rising imports have taken the market share of domestic output and funding constraints have led to weaker domestic reserves" (Ng 2013).

Second, given China's insufficient domestic gas production and lack of gas storage capacity (discussed in Chapter 5), spot LNG purchases are needed to meet seasonal peak demand. These purchases are sourced from distant countries, such as Qatar and Nigeria. Chinese buyers need to pay prices higher than other buyers if they are to compete and "lock down" supply, or spot cargoes will simply switch to other buyers, such as the UK or Japan.

Third, base-load, long-term supplies of LNG remain the most dominant form of natural gas trade in the regions of Asia Pacific, but it remains uncertain if, or how, this geography of LNG supply into China might change. These factors include, for example, the pace of domestic supply, especially unconventional gas, future expansion of transnational pipeline imports, Asia's LNG demand, expansion of old major suppliers such as Australia and Qatar, and development of new suppliers such as Mozambique, Tanzania and the United States. If the volume of LNG imports increases (which is likely), or the proportion of LNG from regions outside Asia-Pacific increases (which is more uncertain), China's official strategy of energy security will pay more attention to natural gas.

Chapter 5 Distributing Gas

5.1. Introduction

This chapter finishes the story of China's gas "supplies" by looking into the actors, institutions, technology and infrastructure associated with gas distribution. As noted in the previous chapter, to supply gas to consumers is to acquire it, either through domestic production or imports, and then distribute it. The traditional GCC/GVC approaches assume that the connection from upstream to downstream is a linear, one-way street. A GPN approach, however, seeks to highlight the dialectical relations among "upstream", "mid-stream" and "downstream". In the case of gas, the mid-stream is functionally integral to both upstream and downstream, as gas producers will not produce if they do not have access to infrastructure that distributes gas to the market, and gas consumers cannot consume if they do not have access to gas supplies. And the "mid-stream" of the gas industry is not a passive component, but represents an active group of players, who have ultimately been shaping the length, connectivity, resilience, robustness, distribution and mode of gas distribution infrastructure, as well as the pricing mechanism that affect both producers and consumers.

This chapter, therefore, seeks to explore the transition in China's gas network infrastructure, which consists of an "anchoring" system (major pipelines) and a satellite one (land-based micro LNG and compressed natural gas/CNG), and the value-capturing behaviours over space of the state and firm actors involved. It is said that the natural gas industry is fundamentally "a network industry" (Evans & Farina 2013, p.27), as natural gas requires infrastructure networks to link sources of production to the geographical locations where it will be consumed. Understanding the gas industry, hence, requires an identification and appreciation of the different types of gas-moving networks that exist, how these systems operate and how their value changes as they evolve.

After this introduction, Section 5.2 analyses China's state-led supply-push gas market development and seeks to understand the mentality, rationale and decision-making mechanism of the national pipeline projects through the detailed case study of West-East Gas Pipeline (WEGP). It helps explain why China's energy governance in the case of official gas infrastructure expansion is highly efficient, which appears to contradict its fragmented character, as explored and argued in Chapter 3. This case study aims to be indicative rather than exhaustive, as it covers only the case of WEGP, because discussion and information on this pipeline are most publicly available. But it is believed that the WEGP case is highly representative. The WEGP was a landmark event in the history of contemporary China's gas industry, as it was the first major cross-province gas pipeline, designed to create a real "national" gas industry. Although this study is also reliant on primary data from interviews, the lack of secondary sources has limited my ability to engage informants to comment on other pipelines to create analyses rich and in-depth enough to improve our understanding of the decision-making mechanism of national gas infrastructure projects. In other words, information bias should be noted and the case of WEGP provides no more than a partial window of how China's gas sector is governed by the state and NOCs. This "partial story" is, however, insightful, as it has effectively explained why China's disjointed, departmentalised and regionalised decision-making mechanism could have fast-tracked a project of an unprecedentedly large scale within such a short period of time.

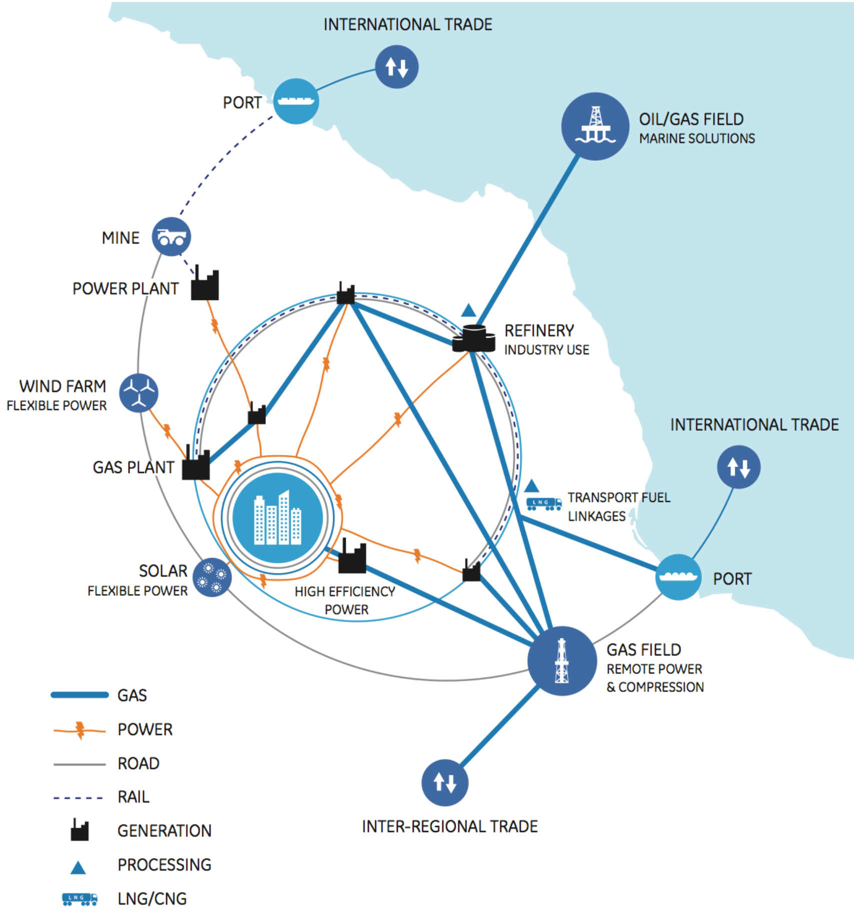
Section 5.3 studies how China's multi-network system of gas transmission and distribution has been formed. It discusses the pipeline boom in the 2000s, which has been responsible for the growth in the E&P and gas consumption, as the former is the systematic prerequisite for the latter. It covers the challenges facing China's gas mid-stream: low pipeline network density, monopoly of NOCs and lack of incentives of NOCs in constructing gas storage facilities. In response, the rapidly growing inland LNG/CNG logistics network, from small-scale LNG/CNG plants to road-based carriers, is offering a more dynamic, and geographically flexible, gas-delivering option to compensate the inadequate and inflexible regional pipeline network. Moreover, the inland LNG/CNG industry is run by a larger number of independent firms, with their own production networks. In other words, the regional gas transport consists of two spatially discontinued production networks, complementary with each other.

The final part of Section 5.3 finds that the liberalisation of the city-gas pipeline industry in the early 2000s has allowed independent firms and provincial governments to fully participate in the industry. Different from the E&P and regional pipeline industries, the presence of NOCs in this part of the supply chain is less pronounced, partly because NOCs do not have the exclusive operating licenses as they do in other areas, and partly because they had no interest and experience in running city-gas business until the creation of CNPC's Kunlun Gas as late as 2008. This part of supply chain is also the most profitable, because they sell gas at end-user gas prices, which are set by the related provincial governments, who have the incentives to maintain the profit returns of the gas distribution firms. However, the prospects of independent gas distribution firms have become more uncertain, when the NOCs have started charting this area. Their entry to the city gas sector is worrisome to independent players, as the NOCs possess unmatched advantages over access to gas sources, political connection, and financial power.

5.2. State-led Gas Market Development: WEGP as a Case

When the gas industry develops, the networks of distribution infrastructure become denser and more diverse. More advanced gas networks involve hub and spoke structures and are even designed to permit flows in reverse, enabling bidirectional links and creating greater flexibility and robustness. As the networks grow, opportunities for value creation increase, representing the “additive nature” of gas networks, where value can be created, enhanced and captured by providing services for gas transport, trading gas, converting gas to a range of end-products (from CNG/LNG to electricity to petrochemicals), backing up intermittent renewable power plants and creating an integrated network of functionality (Figure 5.1). Gas travels by one of the three means to reach users, namely pipelines, ocean-based LNG and land-based LNG/CNG. Globally, the pipeline mode accounts for 89 percent of total gas transport, ocean-based LNG 10 percent and land-based small-scale LNG/CNG 1 percent (Evans & Farina 2013, p.29). These “network modes”, a term coined by (Evans & Farina 2013), represent very different geographies of network, or spaces of flow, and together they create a coordinated, multi-layer network system.

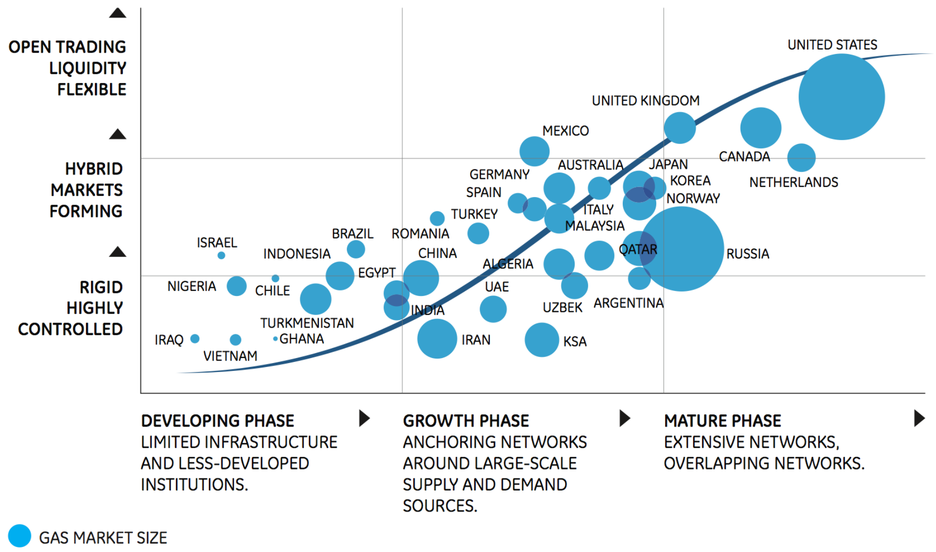
Figure 5.1 An Integrated Network of Gas Value Chain



Source: Evans & Farina (2013, p.66)

General Electric (GE) (Evans & Farina 2013), a global gas player, divides the development level of gas infrastructure, or the "network evolution", into three phases. The developing phase where gas infrastructure is severely limited and is exemplified by countries such as Iraq, Vietnam and Turkmenistan. The mature phase where network is dense and storage capacity is adequately in place, with geographically dispersed but functionally interconnected points of supply and demand centres, can be found in the United States, Canada, the Netherlands and the United Kingdom. Between the two phases is the growth phase, where infrastructure is being built, "anchoring" the long-term networks of large-scale gas supply, and which can be founded in places such as Iran, India and today's China (Figure 5.2).

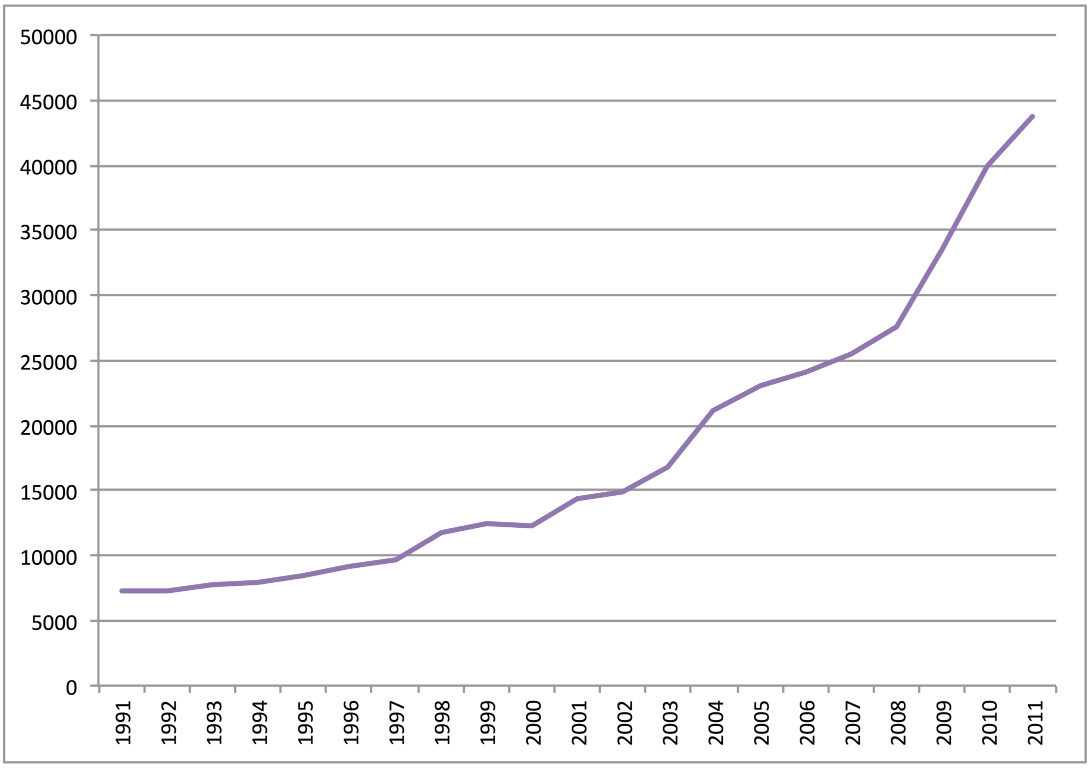
Figure 5.2 Gas Network Growth Curve



Source: Evans & Farina (2013, p.32)

In the early stage of network development, gas infrastructure is characterised by mainly point-to-point, unidirectional connections, in the form of inflexible and regionalised pipeline systems. CNPC constructed China's first long-distance natural gas pipeline from Baxian to Sichuan in 1963 (CNPC 2010). But before the operation of the 12 Bcm WEGP in 2004, China's natural gas economy was only a regional phenomenon and confined to traditional gas-rich areas, particularly Sichuan, due to the lack of long-distance transmission pipelines connecting inland gas sources to coastal cities (which were the main engines of national economy). In the early 2000s, China had only around 20,000 km of high-pressure transmission pipelines; most were built to connect a single gas field to a single user, which was very often a fertiliser plant (International Energy Agency 2002a, p.65). Other users were industrial consumers, and residential consumers in Chongqing, Chengdu and other cities (Fridley 2008). These pipelines were mainly built in the 1960s and 1970s without gas storage facilities (International Energy Agency 2002a, p.65). The central government started to promote the construction of natural gas infrastructure in the 1990s in order to improve inter-regional connections. It was partly because of the significant discovery in the Ordos Basin in the late 1980s, resulting in the first major inter-regional pipeline, the Ordos (Shaanxi)-Beijing Pipeline, completed in 1997, at a length of 868 km and with a capacity of 3.6 Bcm per year (Higashi 2009, p.7). But the construction of gas infrastructure did not accelerate until the beginning of the 2000s, when the central government designed and implemented "a supply-push strategy", which sought to "build large and long-distance pipelines at a time when the downstream demand was not yet in place" (International Energy Agency 2002a, p.26). As a result, the length of natural gas pipeline in China has grown 12.5 percent per year during 2000-2011, more than doubled the rate of 6.1 percent during 1991-2000. In 2011, the total length of China's gas pipeline reached 43,800 km, six times the 1991 level (Figure 5.3).

Figure 5.3 Length in Natural Gas Pipeline in China, 1991-2011 (km)



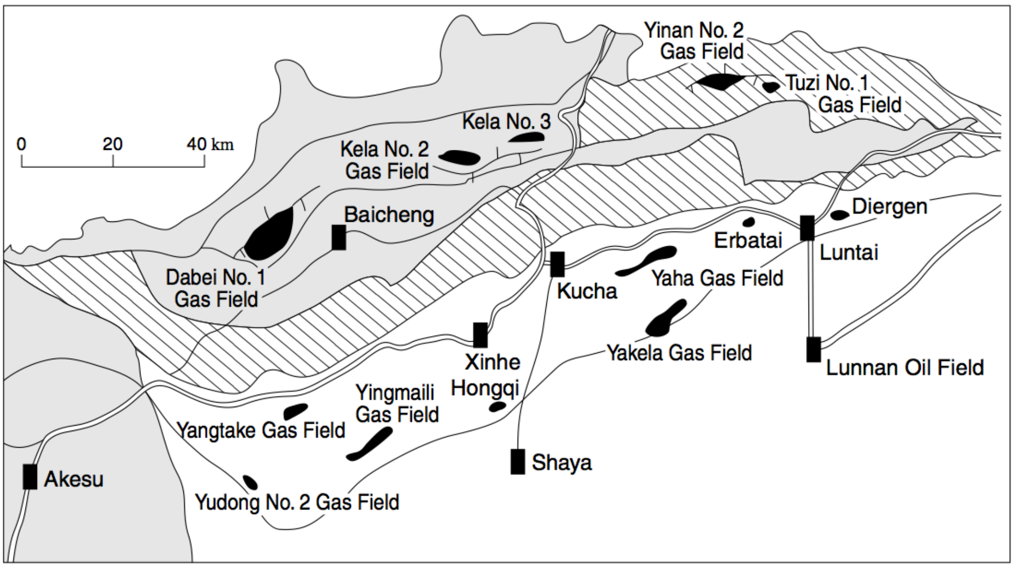
Source: CEIC (2014)

China's supply-chasing-demand strategy in the early 2000s, according to International Energy Agency (2002a), was unprecedented and not proven in the OECD countries, because natural gas can be substituted by other sources of energy, and if it is not attractive, consumers will not adopt it just because it is available - in fact, in the OECD countries, gas markets are mainly led by demand. There was heated debate over this "supply-push" strategy. Advocates argued that it was difficult for the demand side alone to pull gas market development because of the availability of cheap and rich domestic coal supplies. The Chinese NOCs provided the strongest support to this argument, as the top-down, supply-push approach to gas transition, if materialised, would result in a replacement of the coal supplied by other firms by the gas they produced. This section will, first, trace back the historical and geographical background of WEGP and why WEGP made sense to some Chinese political and industry leaders. It then will explore how WEGP as a proposal was turned into a national project in order to shed light on China's energy governance. Finally, it will discuss why foreign partnership collapsed and what implications resulted from this.

5.2.1. Background

Before investigating what implications of the WEGP can be drawn for the institutional context of China's gas governance and relational landscape of different firms, some historical background needs to be provided. Established by the CNPC in 1989, the Tarim Basin Oil Exploration Campaign Headquarters was responsible for exploring oil and gas resources on the Tarim basin in Xinjiang. By the end of 1998, ten large and medium gas fields had been explored and 18 commercial gas-bearing structures had been found on the Tarim basin, yielding 282.6 Bcm of proven gas reserves, and three-quarters of which were discovered by the CNPC's Tarim workforce (Kong 2009a, p.799). In particular, the discovery of Kela-2 gas field in 1998 laid the resource foundation for a cross-country gas pipeline (See Figure 5.4). The gas field was estimated to hold 250.6 Bcm of proven reserve (Table 5.1), and is alone able to sustain a production rate of 12 Bcm for almost 20 years, enabling the whole Tarim basin to sustain a production rate up to 20 Bcm for more than 30 years (Kambara & Howe 2007, p.87, Kong 2009a, p.799). But at that time, neither the Tarim Basin nor western China had the facilities to utilise these resources, and NOCs had to flare most of the associated gas. To improve efficiency and expand market shares, NOCs, mainly CNPC/PetroChina, advocated the proposal of the WEGP.

Figure 5.4 The Kucha-Tabei Gas Area in the Tarim Basin



Source: Kambara & Howe (2007, p.87)

Table 5.1 Oil and Gas Fields in the Tarim Basin

Oil field, gas field, oil/gas field	Area (km^2)	Proven reserves (in place)		
		Crude oil (000 tonnes)	Natural gas (100 mmm^3)	Total (oil equivalent) (000 tonnes)
Kela 2 gas f.	47.1	–	2506.10	20 457.8
Tazhong 4 oil f.	35.7	8137.0	119.27	9 110.6
Yaha oil/gas f.	48.9	4442.9	405.37	7 752.0
Kekeya oil/gas f.	27.5	3065.5	313.55	387.0
Hotanhe gas f.	145.0	–	616.94	5 036.2
Lunnan oil f.	36.6	5113.0	40.33	5 442.2
Yingmaili oil/gas f.	48.3	1950.1	309.75	4 478.7
Donghetang oil f.	16.5	3292.7	13.70	3 404.5
Hade 4 oil f.	66.6	3068.0	7.94	3 132.9
Yangtake oil/gas f.	18.3	567.5	274.29	2 806.6
Jilake oil/gas f.	52.5	782.0	136.80	1 898.7
Jiefangjudong oil f.	14.0	1532.2	34.39	1 812.9
Sangtamu oil f.	18.6	1501.0	18.49	1 651.9
Tazhong 16 oil f.	24.2	976.0	1.32	986.8
Tazhong 6 gas f.	58.0	73.4	85.26	769.4
Yudong 2 gas f.	10.2	142.5	73.32	741.0

Source: Kambara & Howe (2007, p.87)

Besides the secured supply of gas to fill up the pipeline, the demand for gas in the coastal region also justified the proposal of the WEGP. Encountering air pollution and acid rain due to coal consumption, political leaders in the Yangtze River Delta region sought energies alternative to coal in the late 1990s and natural gas became a potential option. When Shanghai Mayor Xu Kuangdi met CNPC President Zhong Yongkang in 1997, he expressed fervent interest in replacing coal with gas from western China:

> When can you transmit 30 bcm of natural gas to Shanghai [from west China]? We look forward to natural gas the same way we look forward to the moon and stars. Currently, Shanghai is severely polluted. If piped to the Shanghai area and used to generate power, the 30 bcm of natural gas can produce 12 million kilowatts of electricity; if allocated for household use, it is enough to meet residential consumption for 30–40 million people; if used to produce fertilizers, it is enough to manufacture 40 million tons. This is an issue of great consequence for Shanghai and the Yangtze River Delta area. I hope CNPC can provide us with the natural gas soon. If you provide me with 30bcm of natural gas, I will turn the skies of Shanghai blue again. However, if you make the move late, Shanghai will consider liquefied natural gas (LNG) from the Southeast Asia (Kong 2009, pp.800-801).

When Xu Kuangdi reported the interest of Shanghai in Xinjiang's gas, then Premier Zhu Rongji expressed his support, instructed Xu to calculate the cost, and asserted "if piped natural gas is competitive, Shanghai will never import LNG from the Southeast

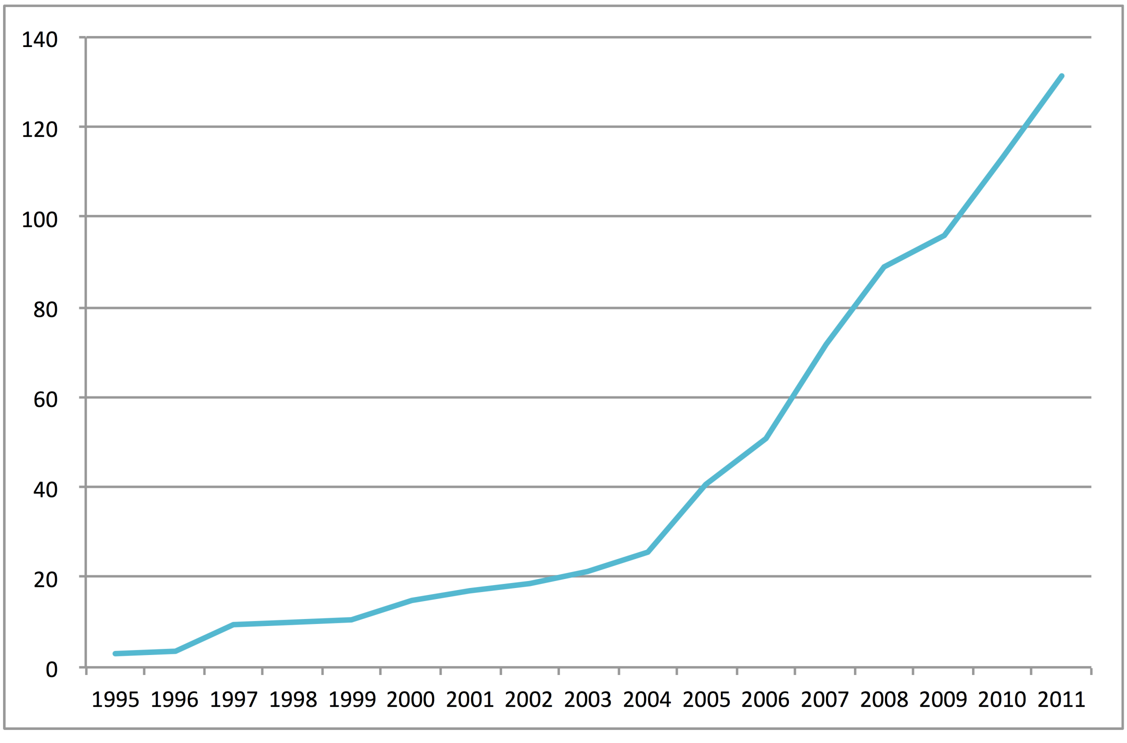
Asia" (Kong 2009, p.801). Premier Zhu's support, to some extent, reflected his concern over China's climbing dependence on foreign sources of energy, as the country became a net importer of oil in 1993, ending the three-decade energy independence since the 1960s (Leung et al. 2014).

Zhou Yongkang was a major advocate of the WEGP. His background and multiple identities in the central government and NOC helped place the WEGP proposal on the agenda of China's top leadership. Before being promoted to vice president of CNPC, Zhou served as leader of the Tarim Basin Oil Exploration Campaign Headquarters between 1989 and 1990. He was then promoted to president of CNPC, before serving the head of Ministry of Land and Natural Resources (MLR), which manages the mineral resources of the whole country. One can reasonably assume that his work experience and personal network have played a vital part in motiving him to come up with the proposal and manage to promote it actively. In 1998, he wrote directly to Premier Zhu Rongji, recommending that the WEGP project be included on the list of national primary infrastructure projects on the grounds that domestic gas was adequately available, that eastern coastal region was badly in need of gas to clean up the air, that domestic pipelines were less risky, and that all developed countries had already developed densely interconnected oil and gas network (Kong 2009).

The Premier was convinced and circulated the letter to Vice Premier Wu Bangguo, who was former Secretary of the Chinese Communist Party (CCP) Shanghai Municipal Committee, and Vice Premier Wen Jiabao. The letter was subsequently distributed among various ministries. Zhou's letter was later recognised to one of the two key factors leading to the actualisation of the WEGP project by Ma Fucai, who was president of CNPC during 1998 to 2004 (Kong 2009).

The operation of WEGP in 2004 was important in the development of China's "national" gas market. Figure 5.5 summaries China's inter-provincial gas trade (turnover) between 1995 and 2011, which can be considered as an indicator of the connectivity of China's sub-national gas flow, and it suggests that China's domestic gas trade started to surge in 2004, when WEGP operated. The year of 2004 is a "watershed" in hindsight: after the WEGP, the formation of China's national gas market took off and more long-distanced pipelines were put in place year after year. Announced in 2000, WEGP was designed to deliver gas from the Tarim basin in Xinjiang and Ordos basin in Shaanxi to consumers in the richer coastal areas, mainly Shanghai and the Yangtze River Delta, at 12 Bcm annually for 30 years (International Energy Agency 2002, p.216). The some 4000 km pipeline traverses eight provinces and a municipality city, namely Xinjiang, Gansu, Inner Mongolia, Ningxia, Shaanxi, Shanxi, Henan, Anhui, Jiangsu and Shanghai (Figure 5.6). The construction is geomorphologically challenging: the pipeline passes through three mountains (Taihang Mountain, Taiyue Mountain and Lvliang Mountain), the Loess Plateau, and cross the Yellow River, the Huaihe River, the Yangtze River, as well as the water areas in the south. 1016mm (40 inch) pipe diameter X70 high grade steel pipe, eighteen 30-megawatt compressor station and 10Mpa high pressure transport were adopted for the first time in China (CNPC 2004, pp.23-24). Total costs of the WEGP, including pipeline construction, city-gas grid build-up, and gas downstream projects in Yangtze River Delta required 120 billion yuan, of which over two-thirds was used for natural gas exploration and pipeline construction in the west (Paik 2012, p.235; Kong 2009, p.801). Albeit the unprecedented scale, technical difficulty and cost, the project was quickly approved in 2002, and completed in 2004.

Figure 5.5 China's Gas Flow between Provinces, 1995-2011 (Bcm/day)



Source: CEIC (2014)

Figure 5.6 West-East Gas Pipleine, Phase I

Source: The Author

5.2.2. Turning a NOC Proposal into a National Project

It is crucial to understand why such a mega project could be passed only two years after it was first proposed, which seems to run counter to China's fragmented energy governance discussed in Chapter 4. Attempting to find what factors are vital when it comes to turning an energy proposal to a national decision, Kong (2009) identified five:

i. presence of a consistent 'issue champion';

ii. associated benefits of the proposed decision for other policy problems;

iii. strength of mobilised and united 'veto players', i.e. those political actors who have the ability to decline a choice being made;

iv. vertical and horizontal support; and

v. clear policy preferences of the central leadership.

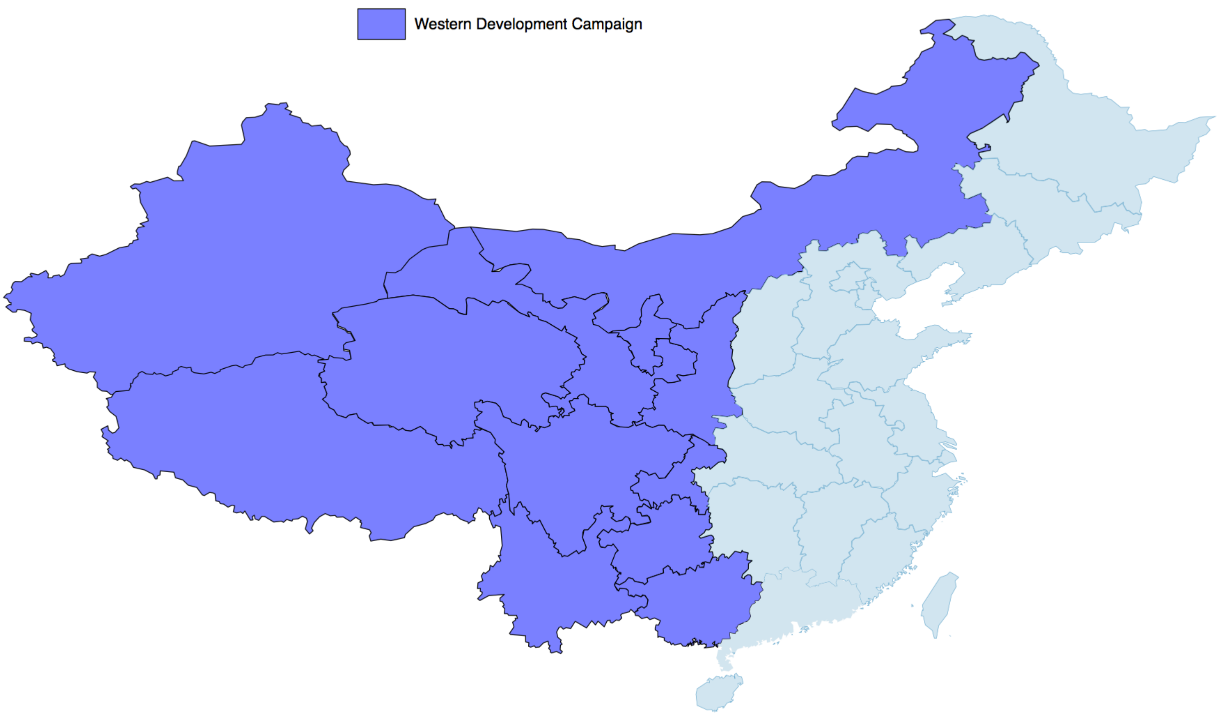
With the framework, Kong attempted to explain why it took Chinese leaders fourteen years to pass the proposal of fuel tax in 2009, reflecting the fragmented nature of China's energy governance and lengthy decision-making. He found that, first, there was not a strong "issue champion" to promote the fuel tax in the central government. The State Administration of Taxation (SAT) was the only active supporter of fuel tax when national tax revenues grew more slowly than national GDP, but its support waned when the growth rate of tax revenues improved significantly in the mid-1990s. Second, the implementation of fuel tax involves reshuffling winners and losers in the vested interests. In simplified terms, while the reform would benefit the country as a whole and improve its tax governance in general, power reshuffles would take place horizontally and vertically. For example, power for collecting fuel tax revenues would be transferred from the Ministry of Commerce (MOC) and its local branches to the SAT and its local branches. Losers would be created inevitably and consensus would thus be more difficult to establish. Third, the biggest losers, particularly local governments across the country which would lose their off-budget revenues in the form of road maintenance fees and transportation fees, would form a "veto group" to argue against it with the central leaders. Fourth, vertical and horizontal supports became disjointed. Finally, no clear policy preferences from the State Council or the CCP top leadership were shown. As a result, "inaction, status quo, prolonged delays, and stalemate evolved into the major characteristics of the decision-making process" (Kong 2009, p.799).

The WEGP, on the contrary, displayed a markedly different case. First, CNPC acted as a strong and determined "issue champion". CNPC was deeply involved in preparing for the economic and engineering feasibility studies and also led the efforts to coordinate interests among different stakeholders. Zhou Yongkang's work experience, personal networks, identity, reputation and letter to the Premier kindled the interest of the top leadership. He advocated the pipeline twice directly to the Premier as CNPC president and as a top government bureaucrat later. The influence of the CNPC can also be confirmed by the fact that Ma Fucai, CNPC's president, was designated as deputy director of the State Council Leading Group for the WEGP Project (Kong 2009).

Second, unlike the fuel tax reform that involves reshuffling of an interest pie, the WEGP created value, enlarged the pie and allowed horizontal and vertical players, state or firm actors, to capture the added value. It would not only make contribution to local revenues in Xinjiang and clean energy developing in Shanghai or the Yangtze River Delta, but it would also create values for a variety of sectors in locations it would traverse, including power and heating industries, the petrochemical industry, manufacturers of steel (for pipeline) and appliances (for consumption), construction and the construction materials sector. Regional job creation, economic growth and tax income were the anticipated results. Consequently, virtually all stakeholders at the central and local level had vested interests in turning the WEGP proposal into an action. Interestingly, the coal suppliers or the local governments in the coal-rich provinces did not serve as "veto players", probably because they assumed that the gas volume of the WEGP is too small to significantly replace coal, that gas prices were less competitive than coal, and that the effect of the coal-to-gas switching would not be significant in the short term. Another reason would be that unlike the oil and gas sector, the coal industry was more disjointed and decentralised in ownership, and less functionally integrated, resulting in weaker voices.

Finally, the WEGP won the unambiguous endorsement of the top leadership on both the energy and non-energy grounds. In addition to benefits on the energy front, the proposed WEGP offered a great stimulus package for Premier Zhu who was concerned about China's economic recession following the Asian Financial Crisis of 1997-1998. More strategically, the WEGP project fit into the 'Western Development Campaign' that President Jiang managed to charter a different development path for China after he consolidated his power. Indeed, the implementation of an energy policy is, however, often not a policy only about energy; rather, it is a product of a broader social-economic strategy. The Western Development Campaign was adopted as a core component of China's national development strategy in mid-1999. The Campaign targeted the 12 provinces, including areas that are traditionally not considered as "western region" (see Figure 5.7) including the eastern region (International Energy Agency 2002a) and envisioned that "by the middle of the 21st century, the Western Region will be transformed into a prosperous and advanced new West, where life is stable, ethnic groups are united and the natural landscape is beautiful" (Grewal & Ahmed 2011, p.163). In other words, the Campaign resulted from the official concern over gaps between China's coastal-inland or East-West areas.

Figure 5.7 Areas Covered by Western Development Campaign



Source: The Author

The economic reform introduced by Deng Xiaping in the late 1970s was in fact a differential spatial planning; it sought to improve the personal income and the economy in the coastal area first and the inland (western and central) areas later. After two decades of the operation of such a discriminatory policy against the inland citizens (who could not relocate freely because of the "household registration system", which tied their citizenship and entitlement to political and social rights to their own cities or villages), internal instability became a pressing issue in the late 1990s. The Chinese political leaders were familiar with the recurrent history of many dynasties being overthrown by poor peasants in the less developed region. The CCP was also aware that their political legitimacy as a ruler would be eroded if they turned a blind eye to the income gap between regions and classes (Brelins 2005). At that time, people living in Shanghai or Beijing earned on average 10 times more than those in the poorest regions of Central China (Handke 2006, p.49). Confronted with the developments in Yugoslavia as well as in Central Asia after the disintegration of the Soviet Union, President Jiang Zemin and its administration were deeply concerned about challenges to China's territorial integrity, and therefore announced the Campaign to address the socio-spatial problems.

The challenges to China's territorial integrity came primarily from the Xinjiang Uygur Autonomous Region, where many Uygurs wanted more political, economic and religious autonomy, and some even advocated the revival of an Independent East Turkestan, which existed briefly in the early 20th century before the founding of the People's Republic of China. Since 1954, the Xinjiang Production and Construction Corps has brought in millions of Han Chinese soldiers and civilians to build cities and engage in mining and agricultural development in less populated areas of the Xinjiang region. The CCP apparatus remains under the control of Han Chinese, and there is little chance of the advancement of Uyghur Party cadres to high levels, even though Xinjiang is technically a Uyghur autonomous region. The locals not only abhor the influx of the Han Chinese and their growing political and economic dominance in the region, they also detest the religious control of the Communist Party. While Islam is allowed in Xinjiang in principle, the Party, an atheist one, controls it tightly in reality, including limiting the number of Uyghurs allowed to go on hajj (an Islamic pilgrimage to Mecca), requiring training of imams to take place in the state-run school in Urumqi and prohibiting non-state-led cultural events (Hastings 2011). The separatists sometimes resorted to violent or even terrorist means throughout the 1990s, including bombings. Chinese authorities claimed that the forces of East Turkestan Independence Movement (ETIM) were responsible for more than 200 terrorist acts, which led to 162 dead and 440 injured between 1991 and 2001, and that the ETIM was closely linked up to the Taliban, which trained the separatists in Afghanistan and northern Tajikistan (Ma 2011, pp.55-56).

China's Xinjiang policy can be summed up as a "carrot-and-stick" approach, which aims at achieving stability and obedience to the rule of the government with harsh law enforcement or military intervention, and with inducements including preferential college admission and more flexible birth quota policies. (Ma 2011) identified energy development as a new carrot, which develop the region's economy and infrastructure by turning the region into China's oil and gas base. To address the South-North income gap within Xinjiang, the central government has encouraged large-scale SOEs to invest in southern Xinjiang since the late 1990s, especially the NOCs (Shan & Weng 2010). Under the banner of the Campaign, several mega infrastructure projects have been launched and materialised, including West-East Power Transfer, South-North Water Transfer, Qinghai-Tibet Railway, and the WEGP.

While this dissertation does not analyse whether ethnic conflict can be effectively tackled by economic means (for example, (Shan & Weng 2010) find that the NOCs only serves to enlarge the economic inequality between the Hans and Uyghurs, given that these state companies prefer to hire Han workers for their technical skills), it finds that the value created by the WEGP is often not captured proportionally by the region. It was because Chinese NOCs, like other central SOEs, do not pay income tax to the local governments, but to Beijing (as they are registered in Beijing) and to Shanghai (as their gas pipeline subsidiaries are registered in Shanghai). Nonetheless, the WEGP project, as a whole, benefits all the locations it would pass through, albeit unevenly, and fits into the spatial policy of the central leaders; hence, it did not encounter strong oppositions and was embraced quickly after it was proposed.

5.2.3. Collapse of Foreign Partnership

The design and implementation phases of WEGP carry useful implications for the role of domestic technology in mega gas projects, state-led demand creation and strategic coupling between gas GPN (represented by IOCs) and regional assets. As mentioned, the WEGP utilised a 40-inch pipe, resulting in an annual transmission capacity of 12 Bcm. Although the pipeline pressure was increased later, and the capacity was increased to 17 Bcm, both figures are internationally low. China's domestic capacity was insufficient to produce pipeline larger than 36 inches in diameter at that time because of poorer technology in steel production. Although BaoSteel in Shanghai, China's largest steel producer tried to upgrade its production capabilities in response to the needs of the project, it seems that it did not succeed in producing pipes that were larger than 40 inches in diameter at a required scale. Internationally, larger-diameter pipelines are usually adopted for long-distance gas transport in order to capture the benefits of transportation economies of scale. For example, Russia adopted 30-Bcm pipelines to sell gas to Western Europe. Even for shorter distanced transportation, the proposal for an Iran-India pipeline considered 48-inch pipes carrying 20 Bcm annually (Fridley 2008). Although the WEGP increased compression to raise the transmission capacity to 17 Bcm, it is still not economically efficient (Paik 2012, Fridley 2008). Moreover, the pipeline is unable to deliver large volume of gas from Central Asia or Russia to China, calling for the construction of WEGP Phase II later (see below).

The resulted high transmission costs also hindered the initial formation of China's gas market in the Yangtze River Delta, once threatening the "supply push" strategy. As a result, CNPC and the central government (NDRC) were forced to reduce prices to stimulate market uptake. My interviews with Beijing Gas and Kunlun Gas suggest that during the construction of WEGP, downstream players were pessimistic that the government or CNPC could find buyers to absorb the 12 Bcm in total (Interview 13). When the WEGP began construction, the International Energy Agency (2002a) identified several risks specific to long-distance gas pipelines, particularly "demand risk". The risks of long-distance pipelines stem from the combination of two factors: (i) investment is not only high up front, but is also irreversibly tied to a specific project once the pipeline is laid; and (ii) transportation costs make up a large share of the market value of the gas. Since the pipeline capacity is designed to meet an estimated demand at a particular time, there would be a risk that the demand is lower than expected or the demand build-up is slower than expected. Pipeline economics is also spatially different in that unlike other industrial investments including oil that can be easily transported by trucks, rail or ship, the demand served by the pipeline is usually linked to a specific region and shortfalls in demand in that region cannot easily be compensated by demand from other areas.

The technical and financial challenge of the project led the government to look for international cooperation, which was against CNPC's wishes (Fridley 2008) as CNCP saw no benefit of giving away the sizeable returns from the project (Paik 2012). Premier Zhu was a strong proponent of international collaboration and under him, the government issued new guidelines to promote interest in international participation. It could also be seen as part of Zhu's attempt to establish a liberal image for China, which had just joined WTO in 2001. These guidelines included the lifting of the restrictions on foreign ownership limits in the project and the form of foreign ownership, such as joint venture. It opened up contraction of urban gas grids and seemed to overrule the "Guidelines for Foreign Invested Industries", which forbid foreign investment in constructing and operating urban water supply and sewage, gas and thermal energy supply networks and required Chinese controlling interest in any gas pipeline projects. Moreover the new guidelines exempted imported equipment from the value-added tax and Chinese customs duties, and loosened land acquisition rules (Fridley 2008).

Temporarily, it seemed that the market access of the foreign players was significantly improved in China's gas industry. Following Premier Zhu's instruction, CNPC issued a tender offer in early 2001 for participation in the project, which included options to take part in upstream exploration in six gas blocks in the Tarim basin, including the Kela-2 gas field, but only on a minority basis. In March 2001, Nineteen foreign companies participated in the bidding, including BP, Royal Dutch/Shell, ExxonMobil, TotalFinaElf, Gaz de France (GDF), Itochu, Marubeni, Mitsubishi, Mitsui, Nissho Iwai, Gazprom, Petronas, Sumitomo, Hong Kong & China Gas, Transgas, China Light and Power (CLP), Energomachexport Russia, Houston Inspection International, and United Technologies. The shortlisted participants announced in mid-2001 included an ExxonMobil-led group with CLP; a BP-led group with Petronas, Mitsubishi, Itochu and Nissho Iwai; and Shell, who submitted its bid alone at the time (Fridley 2008). In September 2001, BP became the first firm to withdraw from the project partly because they found a rate of return of about 12 percent offered by CNPC was not sufficiently attractive. Another reason, according to (Paik 2012), was that BP was more interested in selling gas to China than building pipelines for China. In July 2002, CNPC signed a Joint Venture Framework Agreement with three consortia, including Shell with Hong Kong & China Gas, ExxonMobil with CLP, and Gazprom with Storytransgaz. The project stake, including upstream, mid-steam and downstream, was split in the ratio 55:45 between Chinese firms and the three consortia, where CNPC would hold 50 percent, Sinopect 5 percent, 15 percent for each of the consortia (Paik 2012, p.236).

The foreign partnership suddenly collapsed, however. Fridley (2008) and Paik (2012) believed that CNPC was intending to end the partnership. On the one hand, Premier Zhu retired in 2003, the pressure from the government to engage in foreign participation disappeared; on the other hand, CNPC continued to build the pipeline while negotiating with the foreign companies. When CNPC managed to accelerate the schedule from a 2006 completion to 2004, CNPC made an official announcement that terminated the joint venture negotiation with the Shell-led consortium. My interviews with CNPC (Interview 9), Shell (Interview 7) and a leading domestic gas scholar (Interview 14) suggest that the true picture might be more nuanced and complicated. To these observers, it was more likely that the foreign players walked out by themselves and gave their 45 percent of the project stakes, for several possible reasons. First, the Chinese government and CNPC did not gain the trust of the foreign players in the end. Although the government has promised that they will respect the legality of the deal, the foreign players were not entirely convinced. This impression was reinforced when they felt that CNPC or even the Chinese government did not sincerely want to let foreign players to own their upstream assets. Second, the foreign players were not convinced that CNPC could complete the project on time even with the help of the IOCs. The capacity of steel and pipeline production, and the technical difficulty of the project itself made the foreign players doubt whether it would materialise. Third, the project profitability was dubious, considering that gas prices were not competitive against coal, that the 12 Bcm of gas were not contracted fully at the time, and that the whole gas sector was tightly regulated by the state. In hindsight, Shell admitted that they underestimated the development of China's natural gas market – in fact, it became "demand chasing supply" a few years after the operation of the WEGP.

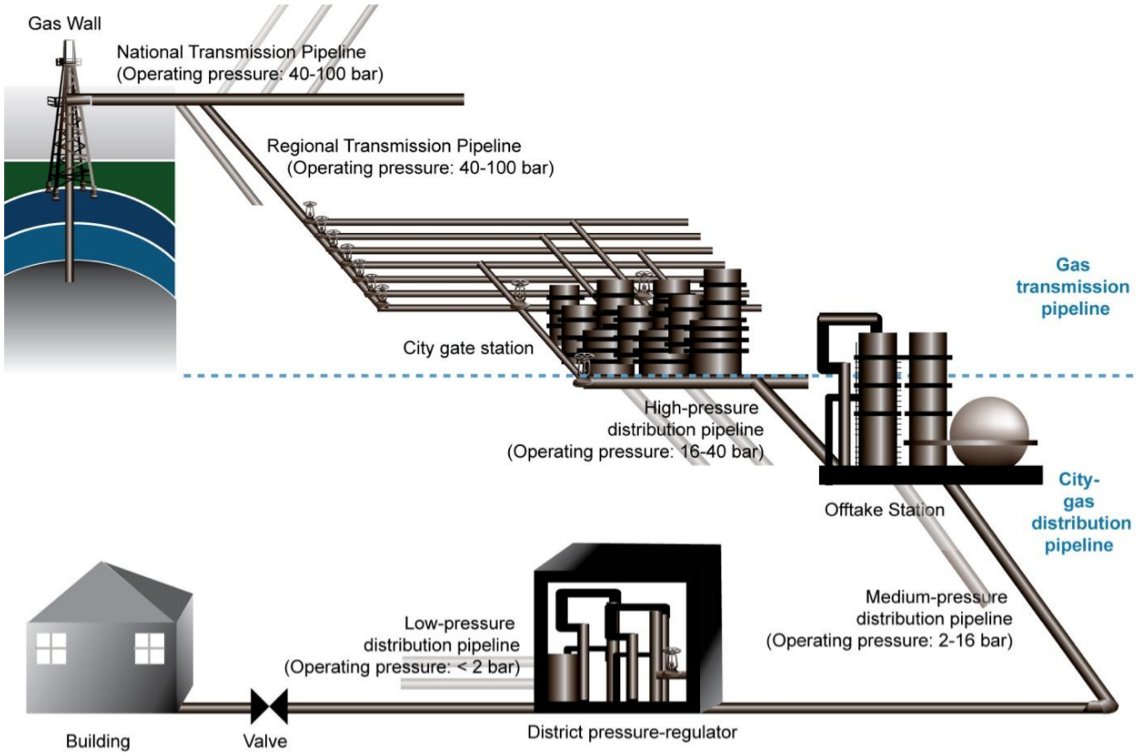
The collapse of foreign partnership in this project has some long-term influence on the structure of China's gas sector. Chinese NOCs became even more inward looking because they could finish the mega project all on their own, and the following pipeline project, such as WEGP Phases II and III, have little if any elements of foreign partnership. Domestic observers judged that if foreign players were involved in the WEGP project, the design and maintenance of the project would have paid more attention to peaking-shaving, contingency, resilience and storage, which are seriously lacking today. These players would have even negotiated with the state for a more liberal and flexible pricing and pipeline access. If they did not walk out, they would have much large access to China's proven gas reserves, opening up the upstream sector to non-NOC, private and foreign players. They would even have participated in the downstream gas distribution business.

5.3. Multi-Network Systems: Transmission and Distribution

5.3.1. Spaces of Gas Flow

One can divide the natural gas transportation system into gas transmission and gas distribution. The gas transmission system is composed of a national trunk line, such as the WEGP, from the gas wellhead across different provinces in China where it divides into regional branch lines such as those of the Ordos-Beijing Pipeline until it reaches a city-gate station in major services cities. The gas distribution system consists of high-pressure, medium-pressure and low- pressure distribution pipelines from the city-gate station to the district pressure regulator (Figure 5.8). The chapter has looked into the case of WEGP-I to shed light on the complication and nature of China's decision-making mechanism for major gas instruction as a state-led spatial project. The rest of the chapter is not going to introduce the background and detail of each of the key pipelines rather, it is going to discuss the implications of China's recent growth in gas infrastructure to value-chain relations among actors as well as to the geographical shift in domestic supply-demand balance, which has significant implications to distributing gas companies and regional differences in gas consumption (which will be discussed in the next chapter). China's construction of long-distance gas pipelines continued after the WEGP-I; in fact, almost all key long-distance natural gas pipelines that exist today were constructed during or after the construction of the WEGP-I, and almost all are constructed and operated by CNPC. The only exception is the Sichuan-East gas pipeline, which is run by Sinopec, or the Yacheng offshore pipeline operated by CNOOC (Table 5.2; Figure 5.9). Despite accelerated construction, the gas infrastructure is still severely limited in China. At the end of 2011, China had over 50,000 km of long-distance, high-pressure pipelines (which do not include city-gas, low-pressure pipelines), of which 36,116 km were built and run by CNPC (International Energy Agency 2012, p.27).

Figure 5.8 China's Multi-layer Pipeline System



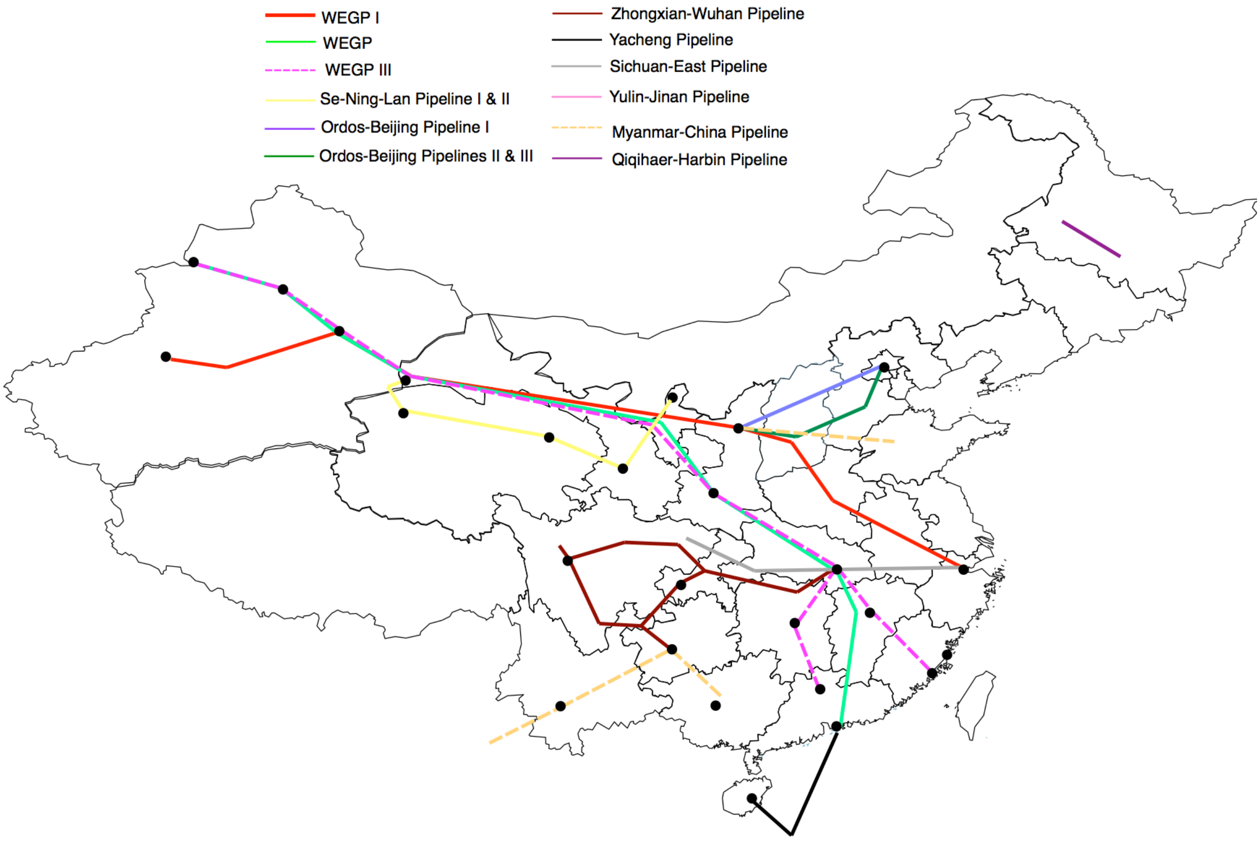
Source: Standard Chartered (2012b)

Table 5.2 China's National and Regional Transmission Gas Pipelines

Project	Capacity	Gas Source	Distance	Operator	Start	Investment
	Bcm/yr		*Km*			*Billion RMB*
WEGP-I	17	Tarim	4200	CNPC	Oct-04	140
WEGP-II	30	Central Asia	8704	CNPC	Jun-11	142
WEGP-III	30	Central Asia	7378	CNPC	2015	125
Ordos-Beijing I	3.3	Jingbian, Changqing	1098	CNPC	Sep-97	N/A
Ordos-Beijing II	17	Jingbian, Changqing	935	CNPC	Jul-05	14.9
Ordos-Beijing III	15	Yulin, Changqing	896	CNPC	Jan-11	14.48
Ordos-Beijing IV	15	Yulin, Changqing	1036	CNPC	2015	N/A
Sichuan-East	12	Puguang	2170	Sinopec	Aug-10	62.68
Sino-Myanmar (China Part)	12	Myanmar	1605	CNPC	Nov-13	24.5
Se-Ning-Lan I	3.4	Lanzhou	953	CNPC	Sep-01	2.25
Se-Ning-Lan II	3.3	Lanzhou	915	CNPC	Nov-09	3.68

Source: Reuters (2013b)

Figure 5.9 China's National and Regional Transmission Gas Pipeline, 2013

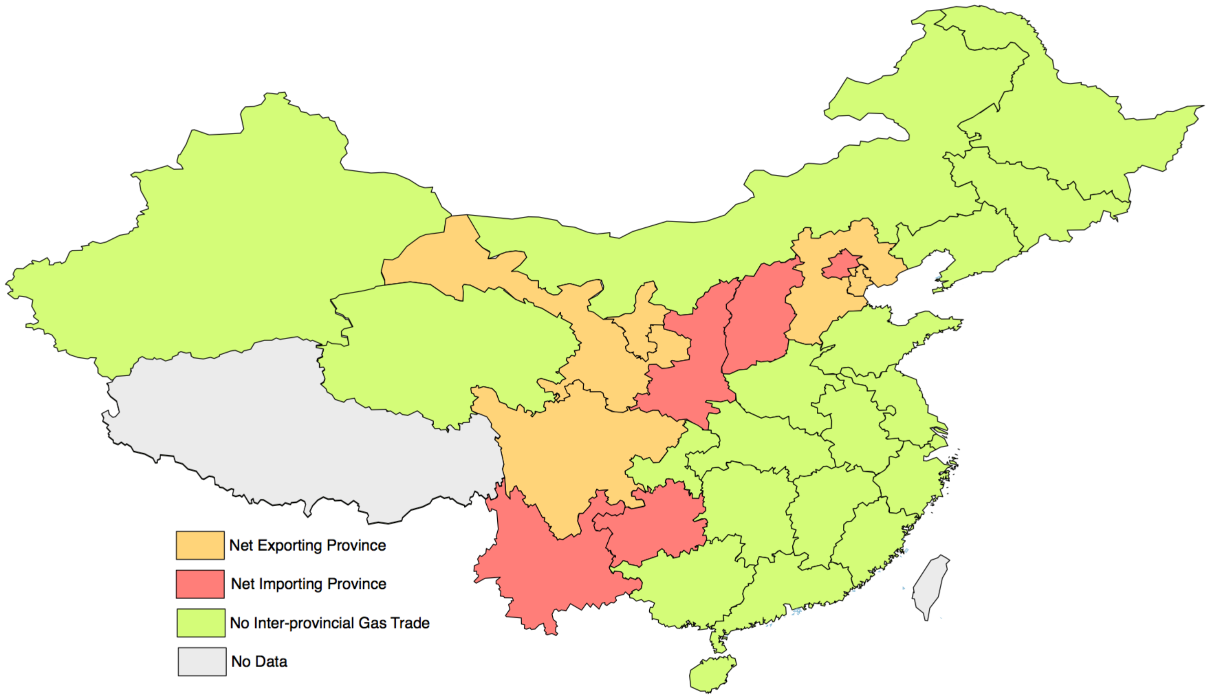


Sources: Based on Paik (2012) & Chen (2012)

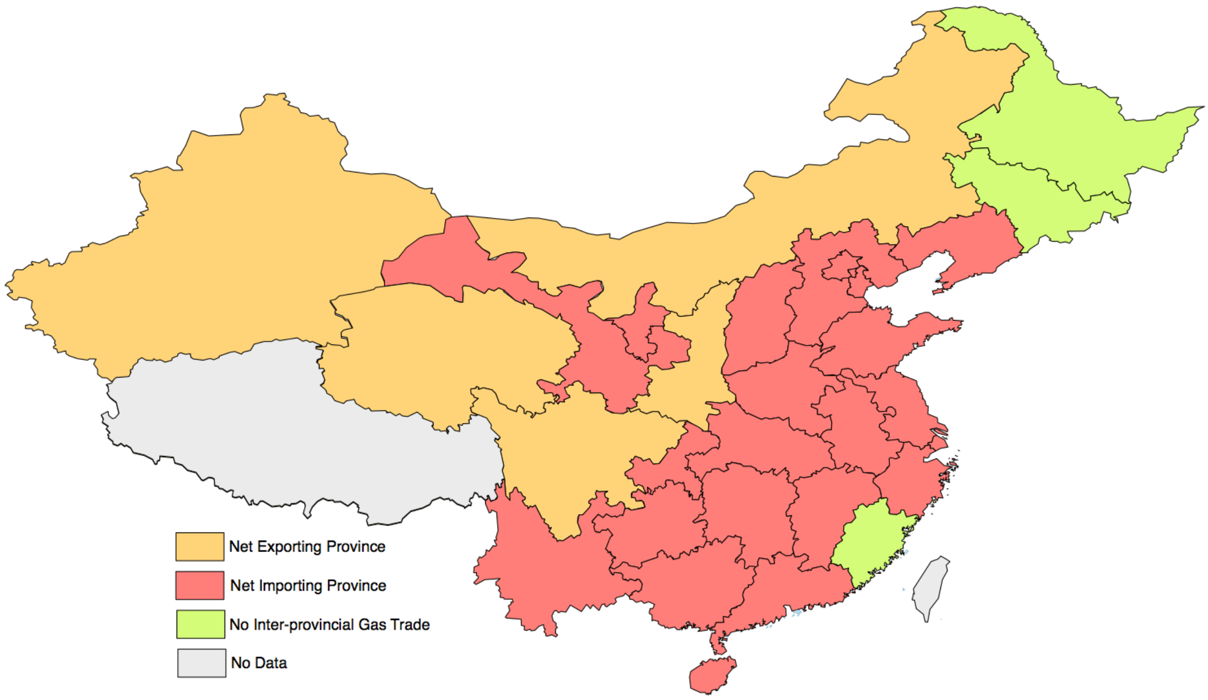
Figure 5.10 compares China's internal gas flow (inter-provincial gas trade) in 2011 with that in 1995. The interconnectivity of China's gas flow has dramatically enhanced directly because of the expansion of national transmission pipelines, and indirectly because of the consequent proliferation of gas production and consumption. It, however, also shows that, three provinces, namely Heilongjiang, Jilin and Fujian, are not connected by any inter-provincial pipelines and are still isolated from the national gas trade network. While Heilongjiang and Jilin produce all the gas they consume, Fujian completely relies on imported LNG for its consumption. The under-development of China's national and regional transmission gas pipelines can be quantitatively indicated by pipeline intensity, which is the ratio of total national transmission pipeline length to gas consumption, which can serve as an aggregate indicator for international comparison. China's pipeline intensity in 2010 was only 0.33 km/cubic metre in 2010, which was significantly lower than the average levels of developed countries, which ranged from 0.8 to 0.9 km/cubic metre (Standard Chartered 2012b, p.12). Despite the fervent efforts of the 12th Five-year Plan (FYP, 2011-2015) to expanding pipelines by 73,000km (Standard Chartered 2012b, p.14), the figure will grow only slightly to 0.36 km/cm by the end of the Plan, which will still be lower than Russia's 0.39 (Figure 5.11).

Figure 5.10 Comparison on China's Internal Gas Flow: 1995 vs 2011

1995

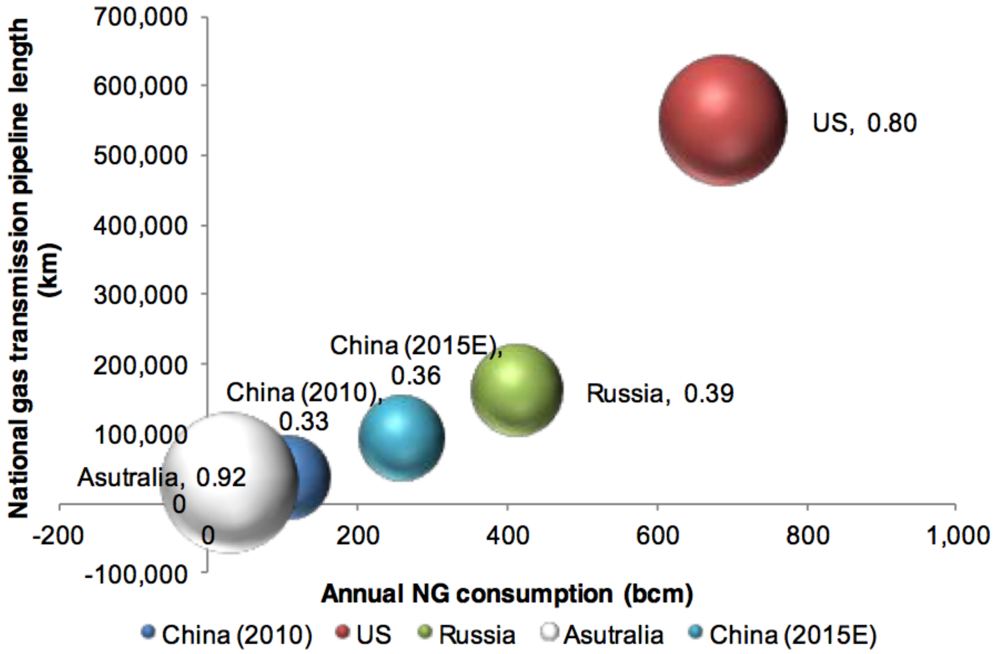


2011



Source: Data based on CEIC (2014)

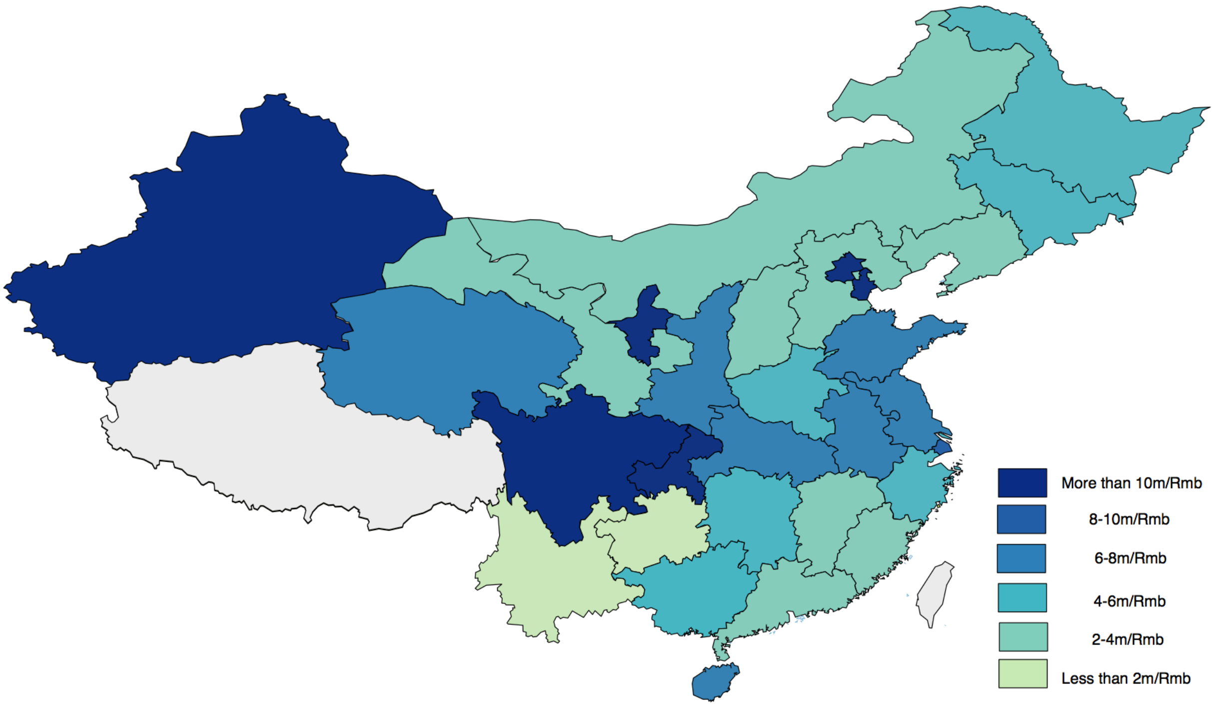
Figure 5.11 Cross-country Comparison in Pipeline Intensity



Source: Standard Chartered (2012b, p.12)

Supplementing the national and regional transmission pipelines are city-gas distribution pipelines, which operate within provinces or cities, with lower pressure. China's under-development of gas pipelines at this scale is no less severe. At this scale, the above pipeline intensity is a less accurate indicator, as natural gas consumption at the provincial level is predetermined by the capacity of gas supply. Another indicator, the ratio of total pipeline length (including all kinds of pipelines) within a province to the province's GDP, is adopted. The rationale behind this indicator is that the relationship between gas consumption and economic growth is more linear than other fuels in China (the gas consumption-GDP elasticity is above 1 on average, meaning that gas demand grows at least linearly along with GDP growth (Standard Chartered 2011, p.34), implying that economic size tends to imply potential gas demand. Figure 5.12 suggests that total pipeline length is severely limited in the economically more developed regions in the south and the northeast. In addition to Beijing (and its adjacent Tianjin), the capital of China where security of gas supplies is politically important (Interview 15), only the major gas-producing provinces are equipped with a densely distributed pipeline network. These infrastructure-induced geographical differences in gas supplies is significant to the economic well-being of those distributing gas companies, whose major locations of service regions systematically determine the size of their business (how much gas they can get and sell) as well as their prospects for business growth. We will come back to the distribution firms later in this chapter.

Figure 5.12 China's Total Transmission and Distribution Natural Gas Pipeline Length to GDP, 2010



Source: Data based on CEIC (2014)

5.3.2. Value Creation and Capture

A. Pipe Makers

Given the expected rapid development in China's pipeline industry, China's leading steel and pipe manufacturers, as the part of the value chain, are well positioned to capture the value added. Since Shengli's SSAW (Spiral Submerged Arc Welded) and Chu Kong's LSAW (Longitudinal Submerged Arc Welded) pipes dominate more than 30 percent of the national market share, analysis of both sheds light on the operation of the value chain associated with China's pipelines. Since the Chinese NOCs are practically the only actors who can be directly involved in national transmission pipeline construction, they are the dominant buyers of pipe and have formed a tight and buyer-driven relation with Shengli and Chu Kong. For example, CNPC and Sinopec currently account for more than 90 percent of Shengli's orders (Standard Chartered 2012b, p.45), and Chu Kong is the only domestic LSAW supplier approved by CNOOC for its deep-sea exploration plans. Since there is a cost-plus clause in the contract between buyers and sellers, the cost of steel in pipe manufacturing, which accounts for more than 90 percent of the cost of sales, can be passed through to the Chinese NOCs. Given the cost-plus clause, the chain is also volume driven: as pipe makers earn only a stable processing fee, the industry's earnings are volume driven by the infrastructure cycle and production capacity dynamics, implying a buyer-driven supply chain. It is estimated that the value created for the pipe making industry during the 12th FYP will amount to 120-222 billion Rmb and the industry will enjoy 7-8 percent of investment return, resulting in 8-18 billion Rmb net profits (Standard Chartered 2012b, p.13). Demand for SSAW and LSAW pipes during the period will reach 15.92 and 10.176 million tons, respectively.

Traditionally, SSAW pipe dominated China's natural gas pipeline projects, although its marker share will drop from 70 percent during 11th FYP (2006-2010) to 61 percent during 12th FYP (2011-2015). SSAW pipes are manufactured using narrower plates or hot-rolled coils, which significantly lowers production costs and have been widely adopted since the 1950s when China lacked the capability to produce wider plates. The spiral welding process permits the production of large-diameter pipes suitable for transporting large volumes of gas, but the resulted welded seams are roughly 30-60 percent longer than LSAW pipes (Figure 5.13). The longer welded seams, and the fact that SSAW pipe is made of X80-grade steel (vis-a-vis LSAW's X120), make SSAW pipes more fragile and less readily applicable in sensitive areas such as deep-water, densely populated areas or regions with critical infrastructure. As said, SSAW pipes dominate the natural gas transmission system with a nearly 70% share in relation to LSAW, but probably because of the safety consideration, its share drops to 52 percent in the high-pressure distribution pipeline part of the city-gas distribution system, according to an anonymous listed gas distributor (Standard Chartered 2012b, p.41).

Figure 5.13 Weld Seam of SSAW (Left) and LSAW (Right) Pipes

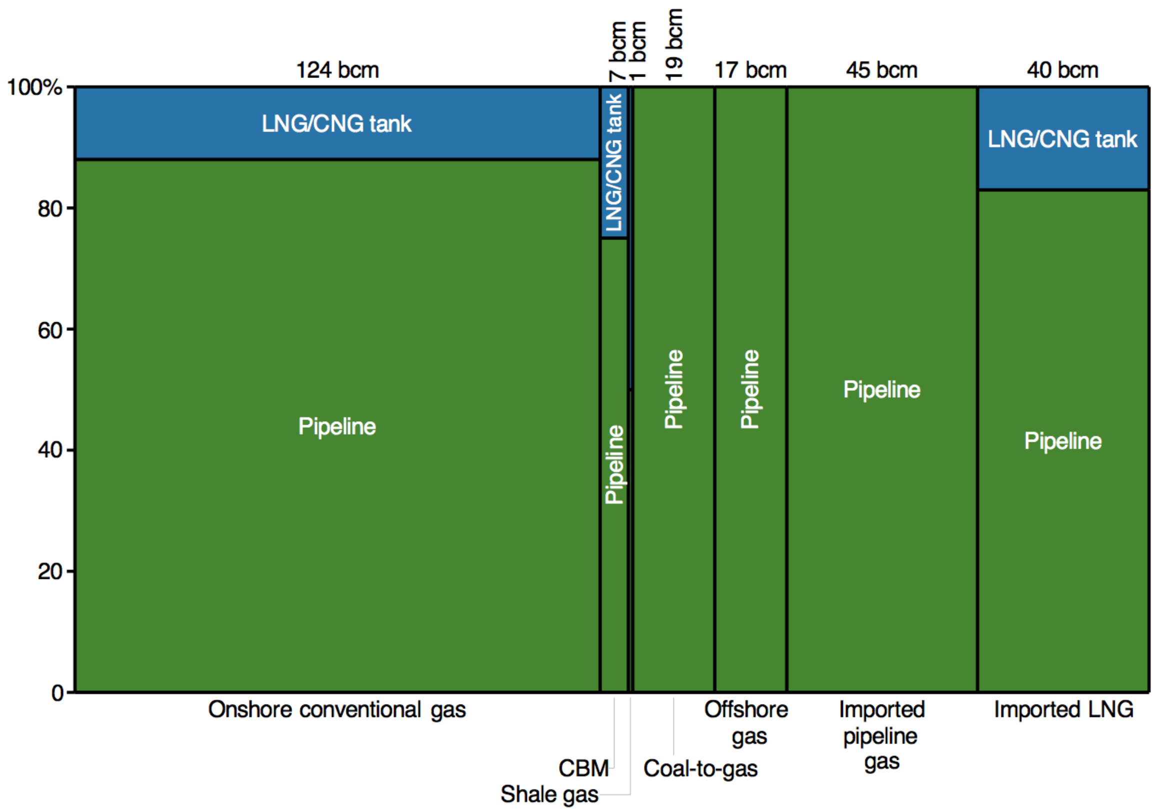
Source: Standard Chartered (2012b)

Chu Kong has the largest capacity of LSAW production, amounting to 1.3 million tons per year in 2011, followed by 0.5 million ton of Baosteel, 0.4 million ton of North China Petroleum Steel Pipe (a CNPC subsidiary), and 0.3 million ton of Shashi Steel Pipe (a Sinopec subsidiary) (Standard Chartered 2012b, p.42). Compared with Shengli, Chu Kong has developed a more diversified mix of buyers, because LSAW, given its high physical strength, can be adopted for other applications such as subsea, deep-sea pipelines and various infrastructure projects such as ultra-high- voltage power transmission towers, and therefore the company holds stronger bargaining power than Shengli, which almost completely relies on the purchase of the NOCs. The wider application of LSAW also means that LSAW makers would have less volatile earnings, as they are less affected by the infrastructure cycle of one industry.

B. Inland LNG Value Chains

While pipelines continue to be the primary gas transport mode thanks to better economics, especially for long-distance and large-volume gas transport, LNG (or CNG for shorter transport) tanks or rail are used to transport natural gas from small/remote gas fields which do not justify construction of pipelines. The LNG is delivered to cities that do not have markets large enough to justify pipelines (base-load supply) or that do not have enough gas from existing pipelines (daily, seasonal or emergent peak-shaving supply). LNG tanks are also used to distribute LNG from receiving terminals to satellite stations for gasification or peak shaving. It is estimated that by 2015 on-land LNG/CNG will account for around 10 percent of China's total domestic gas transport (Figure 5.14).

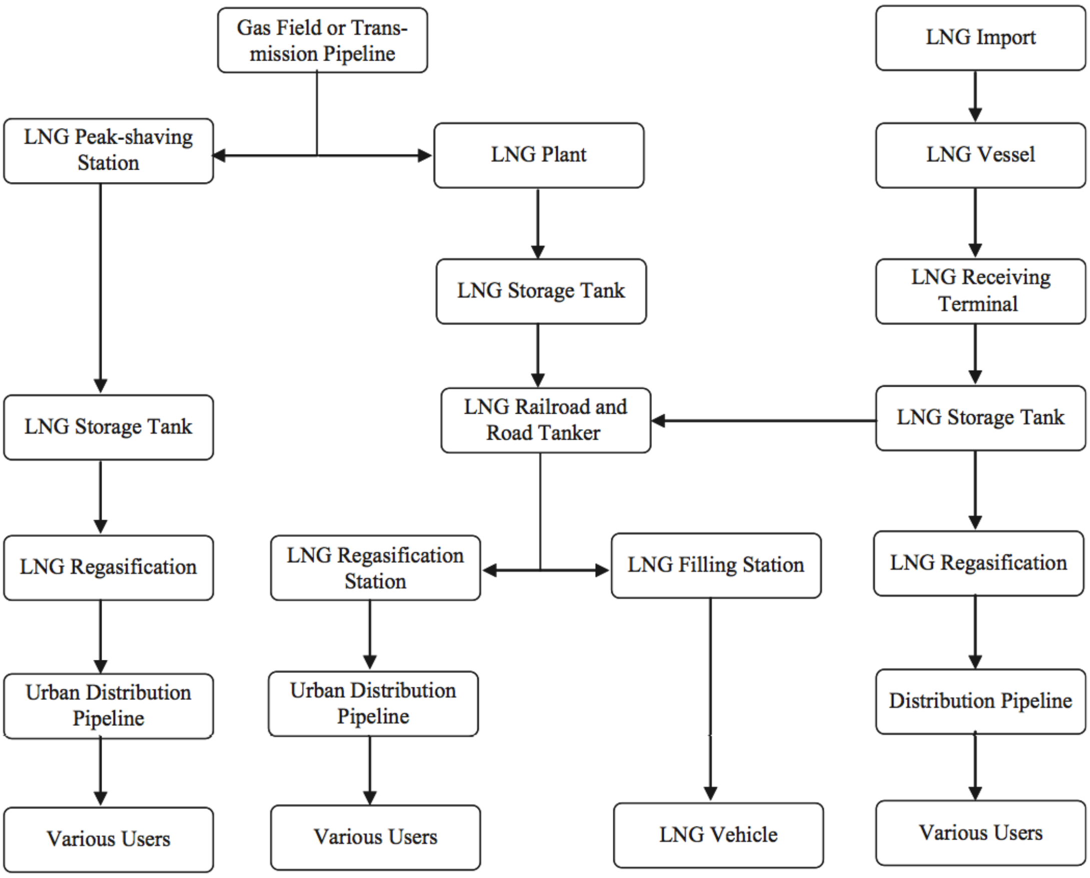
Figure 5.14 China's Gas Transport Mode, 2015



Source: Parthenon Group (2013)

The supply chain of on-land LNG begins with small-scale LNG plants (Figure 5.14). It is estimated that during 2005-2012, at least a dozen of such inland, small-scale LNG plants have been constructed with total capacity of over 1 Bcm (U.S. Environmental Protection Agency 2012, p.115). The majority of these plants use gas from nearby conventional gas fields as a feedstock; some use alternative fuels such as CBM, CMM, coke oven gas, or even coal in one case. Manufacturers include downstream gas distribution companies wishing to lock in supply, companies affiliated with local governments near the gas fields that have received gas allocations through political connections, and affiliates of the major upstream oil and gas companies themselves. Small-scale LNG has been attractive to the manufacturers because, unlike pipeline gas or LNG from the big import terminals discussed above, sales prices are not regulated by the central government. Distribution companies, particularly in richer provinces such as Guangdong, that have not been connected to pipelines have proven willing to offer prices well above that for pipeline gas; their final customers who have no history or vested interest with cheaper pipeline gas have proven willing to absorb the cost.

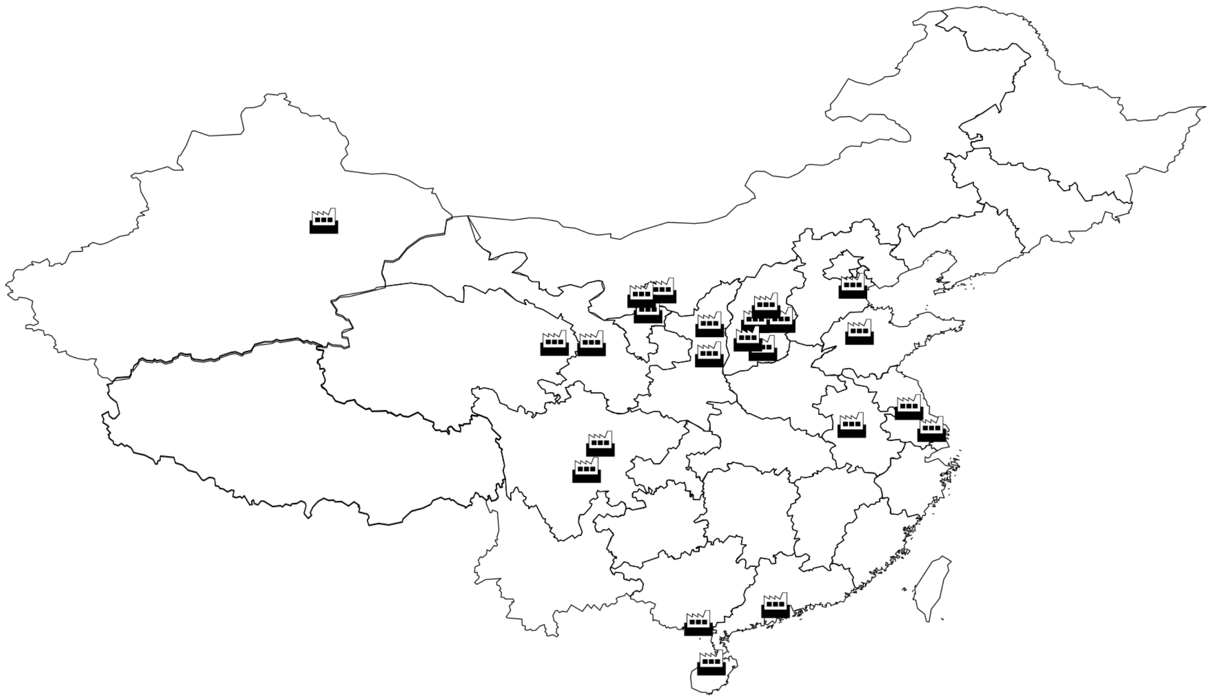
Figure 5.15 China's LNG Supply Chain



Source: Shi et al. (2010, p.7458)

The National Development an Reform Commission (NDRC) looks skeptically at what would appear to be an irrational use of resources that could be shipped more efficiently through pipelines; its 2007 white paper on natural gas utilisation policy clearly forbid gas from large and medium-sized fields from being used for the manufacture of LNG. But while this directive has undoubtedly reduced the number of such plants under construction, it does not appear to have eliminated them completely. The "no build" policy, furthermore, does not apply to domestic LNG plants using nonconventional fuels such as CBM, CMM and shale gas. These small-scale LNG plants are located primarily in the northwestern and central provinces but also Southern China, where pipeline intensity to GDP is among the lowest as mentioned (Figure 5.16). Table 5.3 summaries the existing small-scale LNG plants as well as those being constructed, their locations, capacities and actors involved. It shows that most of the LNG plants are used for base load supplies and they are owned and run by non-NOC actors. A recent report by Financial Times (Gladstone & Zhang 2012) claims that "China's inland LNG capacity expansion presents major export opportunities for foreign technology providers" and those foreign firms "with advance knowledge of China's infrastructure expansion plans, and the specific demands they will create, stand to take advantage".

Figure 5.16 Distribution of Small-scale LNG Plants



Source: Data from Shi et al. (2010, p.7460)

Table 5.3 China's Existing Small-scale LNG Plants

Project	**Location**	**Function**	**Capacity**	**Owner(s)**
			Cubic metre/day	
Shanghai LNG Plant	Shanghai	Peak-shaving	100000	Shanghai Natural Gas Pipeline Network Co
Zhongyuan LNG Plant	Henan	Baseload	150000	Zhongyuan Green Energy High-Tech Co
Guanghui LNG Plant	Xinjiang	Baseload	1500000	Xinjiang Guanghui Industry Co.
Fushan LNG Plant	Hainan	Baseload	250000	Hainan Hairan High-Tech Energy Co.
Jianwei LNG Plant	Sichuan	Peak-shaving	40000	CNPC
Tianli LNG Plant	Jiangsu	Peak-shaving	50000	Jiangyin Tianli Gas Co.
Weizhou LNG Plant	Guangxi	Baseload	150000	ENN Gas Holdings
CNOOC LNG Plant	Guangdong	Baseload	500000	CNOOC
Taian LNG Plant	Shandong	Baseload	150000	Shenzhen Gas Co., Taian Gas Co.
Xining LNG Plant	Qinghai	Baseload	250000	China Oil and Gas Group Ltd.

Longquan LNG Plant	Sichuan	Baseload	50000	Giant Energy (China) City Gas Holdings
Ordos LNG Plant	Inner Mongolia	Baseload	1000000	Ordos Xingxing Energy Co.
Shuntai LNG Plant	Shanxi	Baseload	500000	China Leason Investment Group Co.
Shitai LNG Plant	Inner Mongolia	Baseload	150000	Inner Mongolia Shitai Natural Gas Management Co.
Anyang LNG Plant	Henan	Baseload	100000	Henan Ancai Hi-tech Co.
Hefei LNG Plant	Anhui	Peak-shaving	80000	Hefei Gas Group
Jincheng LNG Plant	Shanxi	Baseload	150000	ENN Gas Holdings
Yincheng LNG Plant	Ningxia	Baseload	300000	Ningxia Funing Investment Group, ENN Gas Holdings
Shuntianda LNG Plant	Tianjin	Baseload	100000	Tianjin Shuntianda Natural Gas Co.
SK LNG Plant	Shanxi	Baseload	250000	Shanxi SK Gas Co.
Kelin LNG Plant	Shaanxi	Peak-shaving	300000	American Hawkins International Investment Inc
Ansai LNG Plant	Shaanxi	Baseload	2150000	CNPC
Lanzhou LNG Plant	Gansu	Peak-shaving	200000	Lanzhou Gas Chemical Group Co.
Hanas LNG Plant	Ningxia	Baseload	1500000	Ningxia Hanas Natural Gas Co.

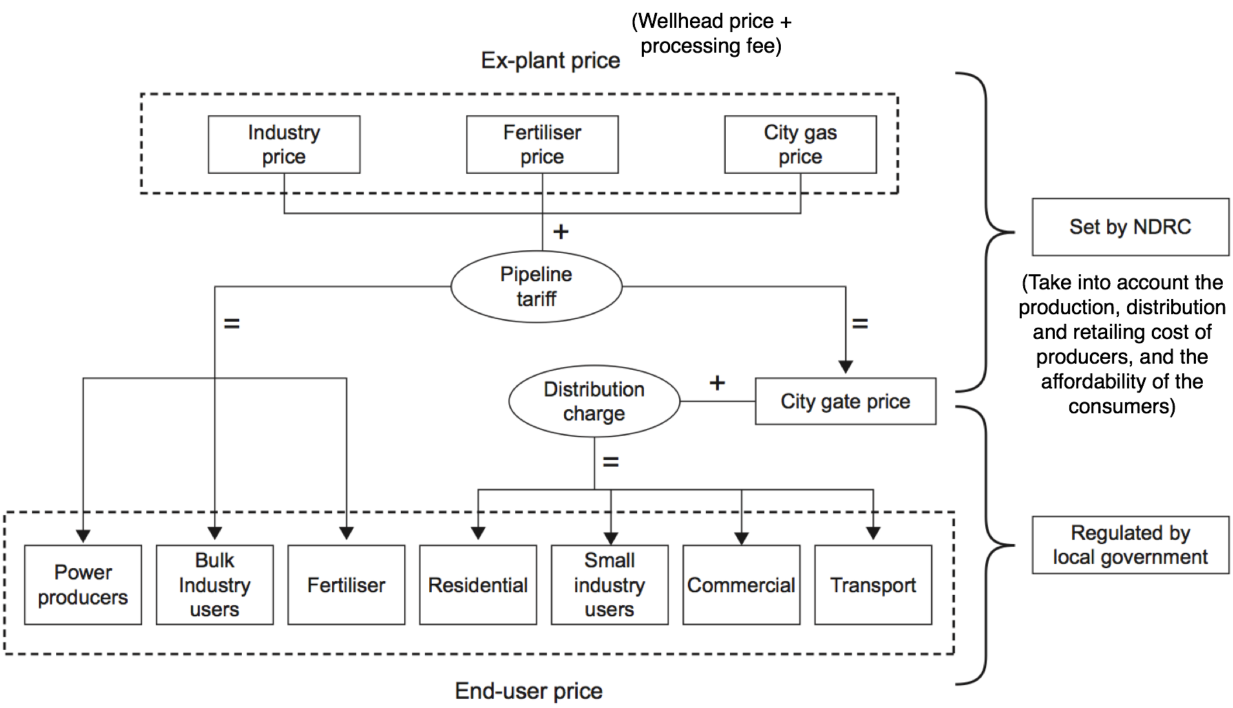
Source: Shi et al. (2010, pp.7461-7462)

Inland LNG is carried by road, rail or water transport modes. According to Wei Hong, President of Xinjiang Guanghui Petroleum Co., one of China's largest inland LNG providers, road transport remains the dominant mode of LNG transport. There were 1300 LNG-carrying trucks operating in 2010. Road transport is economically feasible for delivering LNG within 500 km radius. Rail and water transport are still under research and demonstration phases, but they can deliver inland LNG to farer places economical - 500-1000 km for rail transport and more than 1000 km for water transport (Wei 2010). According to a report prepared by Det Norske Veritas (2011) for the Norwegian Embassy, waterway LNG distribution in China is expected to be optimised to a hub and spoke mode whereby, foreign LNG imports will be received at terminals along the East-North coast, distribution by small-scale LNG carriers will operate along the Yangtze river, and most ship operations will take place on heavily congested waterways.

C. Geographies of Gas Pricing

After reaching the city gates through national and regional transmission pipelines or LNG tankers, natural gas needs to be distributed to the end-users either directly from the gas producers (NOCs) or city-gas companies. Bulk industrial users (especially fertiliser producers) and power plants generally do not buy gas from city gas companies but from the NOCs. Other consumers obtain gas from city gas companies through infrastructure that these distribution companies own and operate (Interview 16). Figure 5.17 shows that wellhead prices, processing fees, and transportation tariffs are set or guided by central government and administered by the NDRC, while local distribution charges (including connection fees), as well as end-user prices, are regulated by local governments. Therefore, to understand what prices the gas end-users pay is to make sense of the pricing mechanism throughout the supply chain.

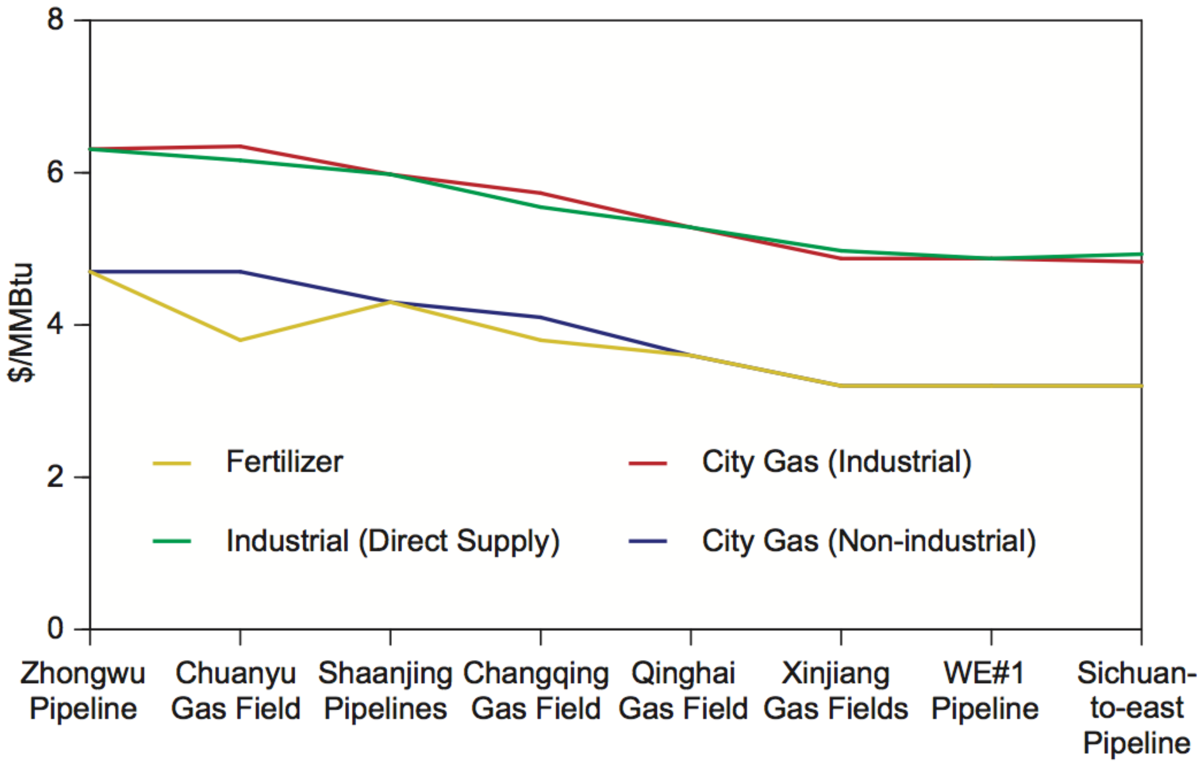
Figure 5.17 China's Gas Pricing



Source: Adapted from Chen (2012, p.311)

Ex-plant Prices: Domestic ex-plant (wellhead plus processing fee) prices for onshore gas are set – well-by-well and region-by-region – by NDRC with different prices for various end users (such as the fertiliser, industrial, residential, and power sectors) via different pipelines. The NDRC guided ex-plant prices across different fields and long-distance pipelines show that wellhead prices for industry are higher than for fertiliser and residential customers (Figure 5.18, note that the lines seem to suggest continuous data, but in fact they denote discrete points). Consumer affordability is still the key determinant for ex-plant price regulation, though it is determined principally by the production cost of natural gas, which depends on the source of local gas supply. Wellhead prices are calculated from a base price (based on project cost, taxation, and loan repayment), plus a gas processing fee and the appropriate margin for producers (for example, an internal rate of return of 12 per cent, although it varies across fields). Processing fees are dependent upon the quality of gas and are negotiated between NDRC and producers. On the other hand, offshore wellhead gas prices are not strictly regulated by the NDRC, as offshore acreage has been open to foreign cooperation, which requires a more market- driven pricing system, since the 1980s. Offshore prices are generally about 13 per cent higher than onshore production prices (Chen 2012).

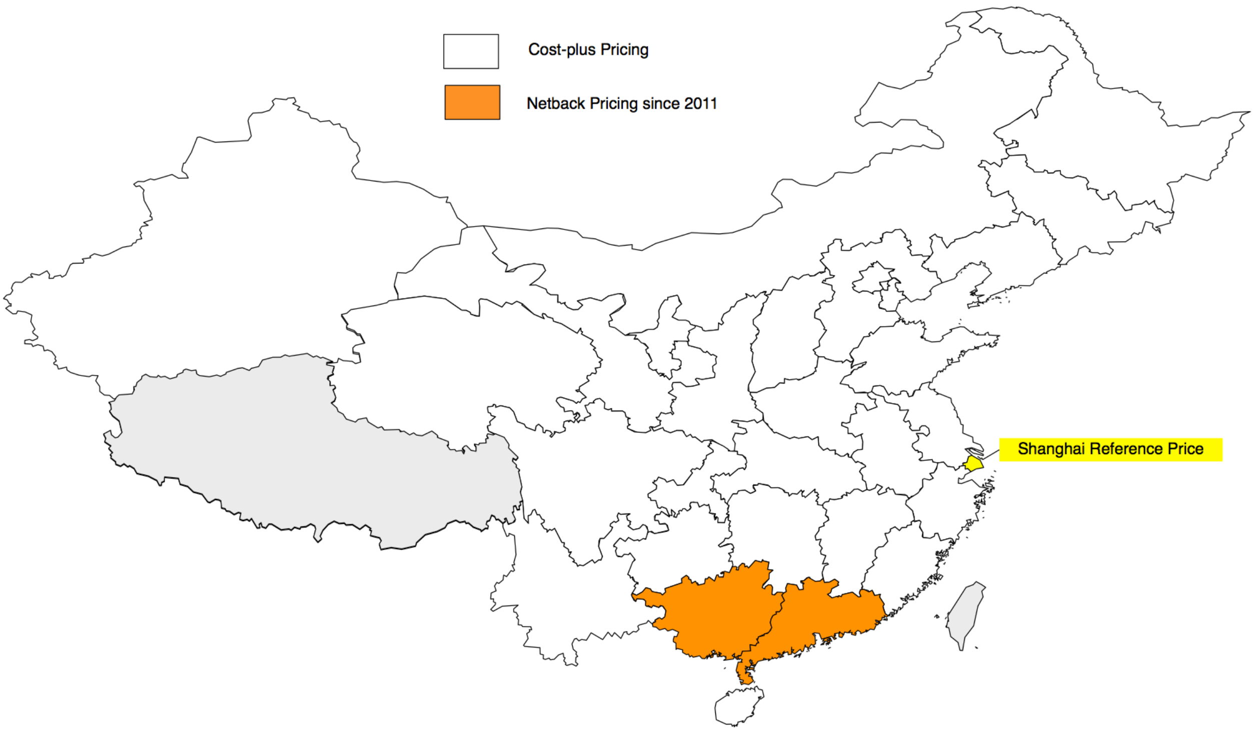
Figure 5.18 Ex-plant Gas Price by Field and Long-distance Pipeline, 2011



Source: Chen (2012, p.313)

There have been mainly two different proposals to tackle the pricing issue over the past few years (International Energy Agency 2012). The first one is to increase the ex-plant price while maintaining the current pricing mechanism, but this has not been pushed forward. The second is to introduce a new pricing formula to better reflect the market signals. At the end of December 2011, the NDRC chose Guangdong and Guangxi as pilot regions to introduce and experiment a new pricing system (Figure 5.19). This new system is based on a netback approach rather than a cost-plus approach. The netback approach, if adopted nationally, means that the city-gate prices for each province will be derived from the Shanghai benchmark price by netting back pipeline tariffs of different gas flows. Since the Shanghai benchmark price is linked to the import price of LPG and fuel oil (which are competing against gas), the new prices is largely determined by market forces.

Figure 5.19 Geographies of Gas Pricing



Source: The Author

The reform is so far limited to Guangdong and Guangxi, because both regions are representative. Guangdong is a relatively large consuming area with over 10 Bcm consumption and sources its gas from offshore domestic production, LNG and started receiving Turkmen gas through the second WEGP at the end of 2011 as well as LNG truck imports from neighbouring provinces. Guangxi, however, is a small market with a demand of less than 1 Bcm.   Under the new system, city-gate prices would be linked 60% to fuel oil and 40% to liquefied petroleum gas (LPG). These linkages reflect the competitors of gas in the industry and household sector respectively, but fail to take into account the competition against coal. These prices are those of Shanghai (customs data), raising the question of when the reform would reach this specific market. The formula takes calorific differences into account, and includes a 10% discount to promote gas use. The system plans for an annual increase in a first stage before moving progressively to quarterly changes. The price-setting formula is as follows (Chen 2012, p.329):

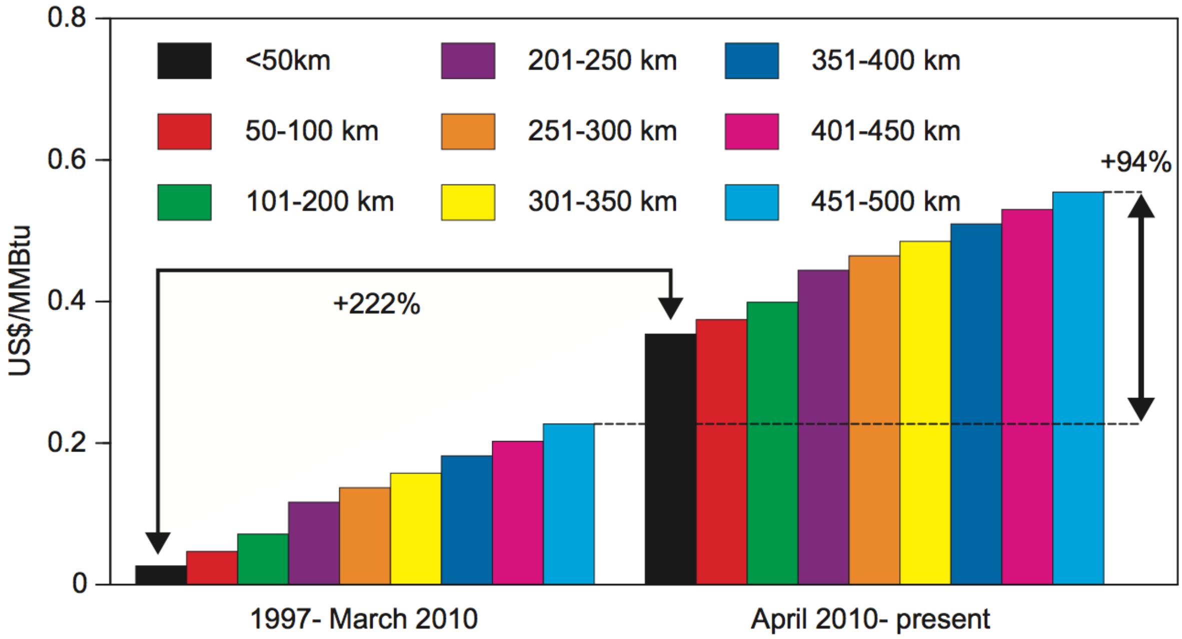
$$P_{gas} = K \times (\alpha \times P_{\text{fuel oil}} \times \frac{H_{gas}}{H_{\text{fuel oil}}} + \beta \times P_{LPG} \times \frac{H_{gas}}{H_{LPG}}) \times (1 + R)$$

P_{gas}	natural gas city-gate price (tax included) in Rmb/ cubic metre;
K	Discount rate, set at 0.9;
α, β	weighted percentage of fuel oil and LPG, 60 per cent and 40 per cent respectively;
$P_{fuel\ oil}$, P_{LPG}	import price during the period in Rmb/kg;
$H_{fuel\ oil}$, H_{LPG}, H_{gas}	Heat content of fuel oil, heat content of LPG, and heat content of natural gas are set as 10,000 Mcal/kg, 12,000 Mcal/kg, and 8,000 Mcal/kg respectively;
R	natural gas VAT rate, currently at 13 per cent

The pricing formula takes into account the competition of fuel oil and LPG against natural gas in the industrial and residential sectors, but it does not factor into the competition from coal. The formula also takes calorific differences into account, and includes a 10 percent discount to promote gas use (International Energy Agency 2012). The policy comes at a critical time when Chinese gas supply sources are increasing and domestic wellhead prices are substantially lower than (around half) import prices. Increasing gas import dependency, in particular from Turkmenistan through WEGP II, has resulted in losses being incurred by CNPC (gas being sold at city-gates at levels lower than import prices). The move to netback pricing reaffirms the government's determination to liberalise gas prices and if widely adopted, it will mitigate CNPC's losses (Chen 2012).

Transportation tariffs: They are largely set by the central government and are principally determined by the distance from each gas source to each city gate. They are considered case-by-case and are based on the economic cost of the pipeline project (construction and operation) plus a 12 per cent IRR (15 per cent for projects involving foreign investment). Besides taking into account differential consumer affordability across regions and distance, a principle of "cost plus reasonable profit" which is based on cost and a payback period for projects, also influences the design of transportation tariffs. For pipelines built before 1995, the transportation tariff was set by the NDRC based on distance. The current pricing mechanism is designed in a way that the regulated transportation tariffs apply to exist- ing gas fields, but for long-distance pipelines built since the mid-1990s, different transportation tariffs are set. In 2010, NDRC substantially raised regulated transportation tariffs, especially for shorter pipelines (Figure 5.20). For existing gas fields, in the case of 500 km, the tariff is $0.68/MMBtu), which implies a unit tariff per 100 km of US$ 4.8 per thousand cubic metres (mcm). For long-distance inter-regional pipelines built in the late 1990s, both ex-plant prices and transportation tariffs are fixed differently for different destinations and end users. In the case of the Ordos–Beijing pipeline, for example, the tariffs are $1.27/MMBtu for Shanxi Province and $2.29/MMBtu for Tianjin. Two-part tariffs were introduced for the Zhongwu pipeline in 2006, with differentiated firm and interruptible tariffs. Out of all the long-distance pipelines, the Sinopec-owned Sichuan-East pipeline has the highest tariff of $3.51/MMBtu to Shanghai, compared with $3.44/MMBtu for the first West–East Pipeline to Shanghai (Chen 2012).

Figure 5.20 Transportation Tariffs for Pipelines of Different Lengths



Source: Chen (2012, p.316)

End-user Gas Prices to Bulk Industrial Users, Fertiliser Producers, and Power Plants: End-user prices are essentially city-gate prices for direct customers (in general not buying from local city gas distributors, but directly from gas producers, i.e. the NOCs or their subsidiaries, such as CNPC's Kunlun Energy), including bulk industrial users, fertiliser producers, and power plants. Traditionally, fertilizer producers have been given the lowest tariff, 30 per cent lower than small industrial customers, to facilitate development in the agricultural sector.

End-User Prices for Non-Bulk Users: They consist of (A) local distribution charges (cost plus margins) which vary between consumers, and (B) city-gate prices.

(A) Local distribution charges: City-gas distribution companies deliver gas to non-bulk end-users through infrastructure which they own and operate and they use different pricing methods for residential and commercial/industrial customers with a variety of additional local charges. For residential customers, a flat connection fee is charged based on the type of gas appliances, such as cooking stoves, water heaters, and boilers. The level of connection fees, and whether such fees are inclusive of a particular gas appliance, vary between geographical locations, and are approved by the relevant provincial pricing bureau. Connection fees are collected in advance by instalments, which include an upfront deposit equal to 30 per cent of the total price, and subsequent instalments. A proposed price by the project developer is then submitted to the local pricing bureau for review, adjustment, and approval. Many local governments have stakes in joint ventures with gas distributors in city gas distribution projects. It is in their interest to facilitate the pass-through of gas costs to end-users. Therefore, connection fees enable city-gas companies to cover the initial cost of developing a new market in a given location, which is crucial when the size of clients has yet reached critical mass (Interview 17).

(B) City-gate prices for city-gas companies: They are determined according to a matrix of ex-plant prices for each gas field, each sector, and transportation tariffs of each pipeline for each city. Based on these city-gate prices, each provincial government fixes retail prices, or the sales prices of local distribution companies, again with sectoral variations. Retail pricing is mainly based on a cost-plus approach, but it takes into account the type of end-user, ability to pay, gas competitiveness against other fuels, gas demand structure and efficiency, and a cost estimate for converting coal gas distribution networks to natural gas. If the wellhead price of a source exceeds a threshold set by each province, a proposed price change by the project developer is normally submitted to the local pricing bureau for review, adjustment, and approval. Price adjustments for the residential sector will normally have a longer review time than for other end-user groups as a public hearing is usually required.

D. Politics of Local Gas Distribution

China prohibited private capital from entering the gas market until 2002, when the government started to carry out a franchised operation system in the city gas market. The release of the Foreign Investment Guide in March 2002 allowed, for the first time, foreign and private firms to establish their own city gas business. Since city-gas pipelines constitute a case of "natural monopoly", which means that when a company has set up its own pipeline network for a city, another company cannot enter that city's business, or it would otherwise lead to eroded market shares, lower profits to cover the sunk costs, and duplicated infrastructure. Therefore, when a company applies to the local governments for an operation license, that license is exclusive and long-term (around 25 years), meaning that the more cities a company can establish its business, the better prospects that company will enjoy for the long run.

This is a geopolitical war of city-gas companies, because it is shaped by local politics in a variety of different geographical locations. First of all, in practice, not every city is open to bidding for licenses. Some local governments are interested in running their own city-gas business and capturing the value more directly, such as Beijing Gas. Currently, there are around 70-80 medium and large city gas projects that are in the hands of the local governments (Lam & Lee 2010, p.30). If the officials do not intend to run the gas business, it is not entirely uncommon that they issue licenses to the firms owned by relatives and friends, and then have it sold to the private companies. Since the whole decision-making is opaque, and the fact that any private company cannot survive without the policy, network and bureaucratic supports of the local officials, the losing bidders normally do not protest against the negative bidding outcomes. Second, since the decision-making is not transparent, the personal network between the bidders and the local officials is extremely crucial. The experience and reputation of the bidders are often not the most vital criteria because the service quality of the bidders should only have nuanced differences and the end-users will not notice the differences, as they will have only one gas supplier in the end. Third, private companies need to negotiate with the local governments the stake distribution of both parties. Practically all local governments would request equity ownership and it is in fact in the interest of the companies. As mentioned, the city-gate gas prices are regulated by the local governments, and therefore joint-venture between gas firms and local governments put both in the same boat, providing incentives to the latter to pass costs to the end-users (Interview 18).

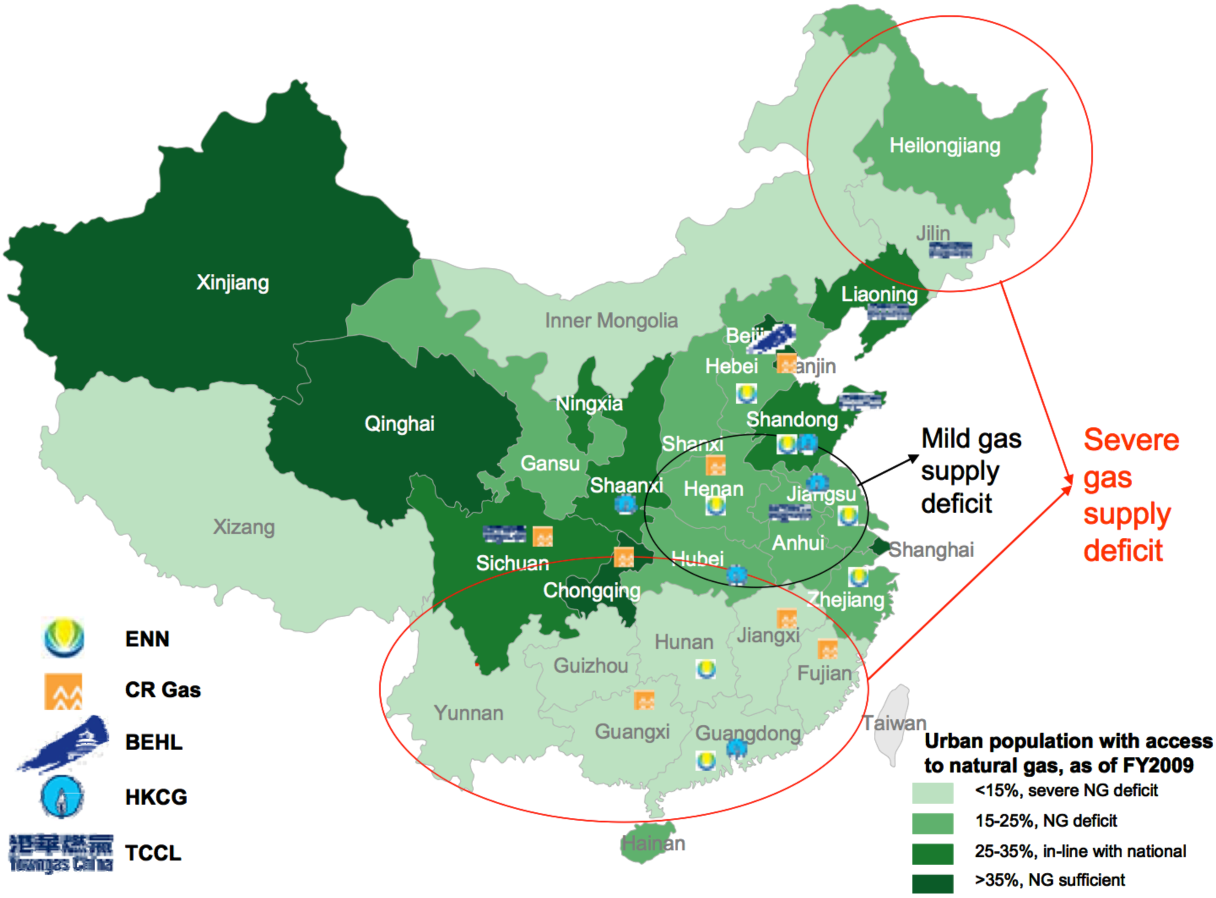
Compared with the production and transmission sectors, which are controlled by the NOCs, the distribution sector is very fragmented and competitive. A Goldman Sachs report found that the top 10 distribution firms took up 32 percent of the market in 2010, and they are Beijing Gas (6 percent), China Resources Gas (5.2 percent), Shenergy Company (4.2 percent), ENN (3.9 percent), Towngas China (3.8 percent), China Gas (3.2 percent), Kunlun Energy (2 percent) and Shaanxi Provincial Natural Gas (2 percent) (Paik 2012, p.226). These firms are of diverse ownerships, for example:

i. Beijing Gas is a gas firm that is wholly owned by the Beijing Enterprise Group, a provincial-government owned enterprise that is developing businesses outside Beijing;
ii. China Resources Gas, listed in Hong Kong, is majority owned by China Resources Group, a SOE with a history longer than People's Republic of China;
iii. ENN is a private firm that is listed in Hong Kong; Towngas China, listed in Hong Kong, is majority owned by Hong Kong-based investors;
iv. China Gas, listed in Hong Kong, has a "colourful" ownership structure, where major shareholders now include Liu Ming Hui (founder of China Gas), Fortune Oil PLC (a company listed on the London Stock Exchange Main MarketBeijing Enterprise), SK E&S Co. Limited (a subsidiary of SK Group in Korea), Sinopec, GAIL Limited (an integrated gas company in India listed on the Mumbai Stock Exchange);
v. Kunlun Energy is majority owned by PetroChina, listed in Hong Kong and in charge of PetroChina's national gas pipelines and gas sales to non-residential users, including bulk industrial consumers and gas stations.

Some analysts expect that Beijing Gas, China Resources Gas and Kunlun Energy have bigger opportunity to acquire and secure more projects through M&A or greenfield development by leveraging their influential SOE status.

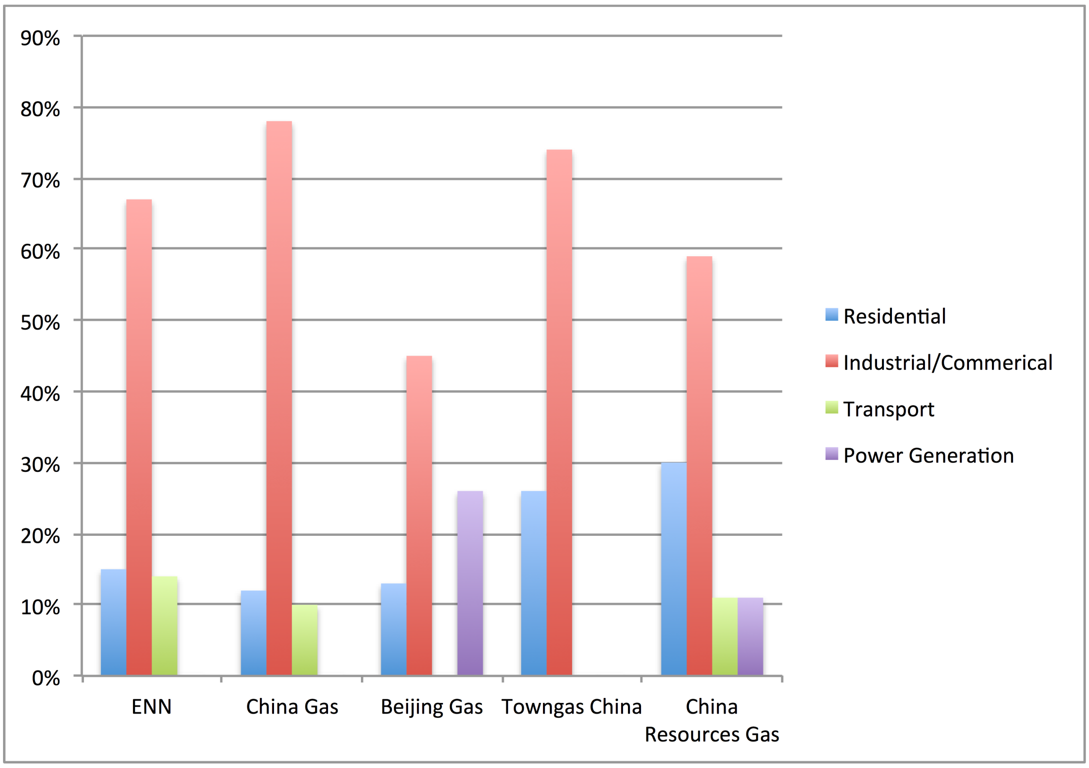
Besides their different investor backgrounds, their geographical and sectoral profiles are also diverse. Given the 90 percent correlation to equity performance of China's gas distributor, understanding the geographical coverage and accessibility of upcoming new gas supply is vital to understanding their future profitability (Standard Chartered 2011). Figure 5.21 shows the major geographical presence of selected gas distribution firms and their respective accessibilities of urban population to natural gas. Firms with business mainly in the Southeast, Southwest and Northeast China are currently underdeveloped due to insufficient supplies of natural gas, including China Resource Gas, Towngas China, Hong Kong and China Gas and ENN. Before the new gas kicks in, these firms have been diversifying their businesses geographically by maintaining or setting foot in provinces with more abundant supplies. Forward-looking investors are more interested in these firms as they will grow significantly faster when China's new gas infrastructures reach them. Since end user prices are set by local governments instead of central government, local administrations in provinces with low penetration rate of pipeline will more likely to raise prices to encourage infrastructure investment (Lam & Lee 2010). Their sectoral profiles also affect their long-term prospects. In China end-user gas prices for residential consumers are more difficult to adjust than those for industrial, commercial and transport ones, and this means that there are delays and an inability to pass on costs in the residential gas market. Hence, higher concentration of a firm on residential gas sales, such as Beijing Gas and Towngas China, might increase cash flow risk (Figure 5.22).

Figure 5.21 Accessibility or Urban Population to Natural Gas and Major Geographical Presence of Major Gas Distributors



Source: Standard Chartered (2011, p.11)

Figure 5.22 Gas Sales Mix of the Selected Distributors



Sources: Standard Chartered (2012a), Paik (2012)

It is worth mentioning the entry of NOC to the city gas industry in recent years, a phenomenon that alarms domestic gas distributors but is sometimes unheard of by IOC leaders in China. My interviews with Towngas China, Beijing Gas and China Gas (Interviews 15, 16, 17 & 19) found that, for a long time, Chinese NOCs are not particularly interested in city gas distribution business because gas used to be a marginal fuel and its market size is small compared with oil and with the bulk non-residential gas market. In other words, NOCs do not have any experience in running city-gas businesses, which require them to communicate with residents directly and provide quality after-sale services. My informant from Towngas China claimed they started noticing the shift in dynamics when CNPC/PetroChina announced the establishment of Kunlun Gas in 2008 (Interview 16). Some earlier activities already show the kindled interest of CNPC in the city gas business. In 2006, PetroChina sided with Aptus Holdings to establish and operate the Huayou Company which has brances in Hunan and Changde and the Hunan branch is mainly tasked with establishing pipeline from Changsha to Changde and supplying gas to urban residents in Changde. In late 2006, CNPC's subsidiary China Petroleum Pipeline Bureau (CPPB) signed a framework cooperation agreement with Zhuhai Pipeline Gas Company (ZPGC) whereby it acquired an 85 percent stake in the latter. To set foot in the city gas sector, CNPC established a specialised city gas company named CNPC Pipeline Gas Investment Co. Ltd, which has obtained exclusive city gas marketing licensees in 46 cities in 14 provinces. On 20 August 2007, the NDRC announced the first Natural Gas Utilisation Policy, which called for higher utilisation efficiency of gas and signaled that city gas use fulfilled this goal. In August 2008, CNPC established Kunlun Gas by injecting city gas assets from CNPC's China Huayou Group Corp, CPPB, Sichuan Petrolem Bureau, CNPC Jilin Petroleum and CNPC Shenzhen Industrial Company, including 100 city gas projects in 23 cities. In November 2009, CNPC put several city gas assets up for sale on the China Beijing Equity Exchange (CBEX) and the Shanghai United Assets and Equity Exchange (SUAEE) and had Kunlun Gas acquire the assets on sale in order to further integrate CNPC's city gas business (Paik 2012). Organisationally, Kunlun Gas is now under PetroChina and CNPC Hong Kong (the part listed in Hong Kong); Kunlun Gas will be the operator, while CNPC Hong Kong will serve as capital provider.

Some IOCs which have E&P assets but do not have city gas business in China have yet heard of Kunlun Gas; for example, a Vice-president of Shell China I interviewed admitted that he had only learned about Kunlun Energy, which is a listed CNPC subsidary, probably because Kunlun Gas is not listed and therefore its information is far less publicly available (Interview 7). To domestic gas distributor, Kunlun Gas is a game-changing "nightmare" to them, because it enjoys advantages incomparable when it comes to market expansion. Compared with gas distributors, Kunlun Gas enjoys direct supplies of gas from CNPC or Kunlun Energy and the internalised and guranteed security of gas supplies is extremely attractive to local governments. Moreover, since Kunlun Gas is part of CNPC, their networks with the local governments are immense. When the senior staff of Kunlun Gas I interviewed handed me his business card, it displayed not only his position in Kunlun Gas but also his senior title in the Communist Party in the province (Interview 13). With his respected position in the Party, he told me rather proudly "I can meet with the governor of the province anytime I want. I do not need to deal with lower-rank officials such as mayors". This person also shared that Kunlun Gas would probably be integrated with Kunlun Energy during 13th FYP (2016-2020) and set to become China's largest gas distributor by 2020 (Interview 13). Asked if the poorer quality of after-sale services of Kunlun Gas would affect their market expansion, my Beijing Gas informant said "no" because "one city has only one gas distributor, so the residents can neither compare nor choose" (Interview 15).

Sinopec has also shown interest in the downstream gas business and attempted to team with ENN to hostile-take over China Gas starting in December 2011. They made a $2.15 billion offer for China Gas, which was more than 150 times the size of China Gas by revenue. But the offer met with stiff resistance from Liu Minghu (Founder of China Gas), who found a host of allies consisting of Beijing Enterprise Group and Korea's SK Group. After nearly a year of equity battle, Sinopec and ENN dropped bid in October 2012 and instead Sinopec signed a strategic agreement with China Gas. Under the agreement, Sinopec and China Gas will set up joint ventures aimed at jointly developing the country's liquefied-petroleum-gas retail market and compressed-natural-gas refilling stations in China. China Gas will also have first priority in getting gas from Sinopec for its distribution (Lee & Ho 2012). This was the first hostile offer in China by a state-owned business for a private company and to certain extent, reflected Sinopec's desperate attempt to enter into the city gas business and level with CNPC. It remains a enigma how Liu Minghu could fight off Sinopec and ENN. My informants from Beijing Gas and China Gas either withheld such information or honestly did not have a clue, but their educated guess was that CNPC (a strategic partner with Beijing Gas) might have been involved in order to prevent Sinopec from becoming a competitor. An influential gas expert from China Petroleum University told me during the interview that he had predicted Sinopec's failure. When Sinopec consulted him about the takeover attempt, he earnestly stated that it would fail, because "what Sinopec is doing is too big a move, creates negative public perception on NOC and annoys the central leaders". He pointed out that the move resulted from Sinopec's new chairman Fu Chengyu, who used to chair CNOOC during its unsuccessful 2005 bid for U.S. oil company Unocal Corp. Since CNOOC is the most internationalised NOC in China, Fu was used to doing business by market rules and mistakenly believed that he could do whatever he wanted as long as the market allows. What Fu missed was the backfire from the central leaders' concern about public perceptions of the NOC monopoly. The expansion strategy of Kunlun Gas is more acceptable in terms of political correctness or public relations: Kunlun Gas never acquires a large firm at one attempt, but it acquires small firms or assets of a large firm one step at a time.

5.4. Conclusion

This chapter has outlined the trends in the development of China's gas-moving infrastructure and concluded that it has volumetrically increased, geographically expanded and organisationally diversified, particularly after the operation of the WEGP and other sequent infrastructure. The analysis of the WEGP has confirmed the significance of the personnel networks between NOCs and the central leadership to gas supply chain: Notwithstanding the underlying reasons of supply (in the Western China) and demand (in the Yangtze River Delta), the strong advocacy of Zhou Yongkang, top leaders of NOC (CNPC) as well as central government agency (MLR), proved to be vital to turning the justified proposal into a actualised project.

The fragmented energy governance, discussed in Chapter 3, did not prevent from the rapid realisation of the WEGP and it was only because such a project involved the creation of new value, instead of re-shuffling of the existing value that would offend the vested interests. Since it benefited every province the WEGP traverses, though disproportionately, the interests and opportunities united both the central and local actors. In other words, China's energy governance is both disjointed and opportunistic. The coal suppliers or the local governments in the coal-rich provinces did not serve as "veto players", probably because they assumed that the gas volume of the WEGP is too small to significantly replace coal. The absence of a powerful coal alliance in China also resulted in lower bargaining power compared with that of the oil and gas alliance.

Moreover, although China's energy governance has been increasingly departmentalised and localised, the top central leaders, if sufficiently determined, could still pass and implement a national project via their influence at both the bureaucracy and party levels. But this largely depends on the personal authority and background of the leaders concerned; in authoritarian states like China, checks-and-balances and chains of command are less institutionalised. Since the Western Development Campaign had actually become the official ideological campaign of the Jiang-Zhu administration that cannot be easily challenged, under the banner of this campaign the WEGP encountered least political opposition. Besides, the collapse of foreign partnership in the WEGP has made Chinese NOCs even more inward-looking because they could finish the mega project all on their own, and the subsequent pipeline projects have minimal to no element of foreign partnership.

Despite the fact that China's gas delivery system has become more resilient, flexible and adaptable, it has just climbed through the developing phase into the growth phase, meaning that it is still underdeveloped by international standards but is set to grow rapidly in the decades to come. Moreover, like other parts of the value chain, the mid-stream (national and regional transmission) requires different tiers of suppliers (for example, from steel producer to pipe makers) to work together to produce a network of value. The downstream (local distribution) has attracted and allowed the largest number of players of different ownership structures (from national, private domestic to foreign capital) compared with the upstream and midstream, and their geographical and sectoral profiles has significant relevance to their future performance.

Finally, the "geopolitics" of local distribution firms appears to be more intense when the upstream and mid-stream oligarchy (i.e. NOCs) is setting foot in the downstream, and the legal procedures and regulation concerned remain opaque and sometimes unreliable. The reason for the kindled interest of NOCs in downstream business is that the sector is less regulated than the other segments of the value chain and thus more profitable, which helps in hedging any losses from gas imports: passing costs on to buyers here is institutionally easier than at E&P. NOCs also find that liquifying domestic gas and selling LNG as a transport fuel is even more profitable (the NDRC announced a new Natural Gas Utilisation Policy in late 2012, encouraging natural gas vehicles), as LNG prices are much higher than the regulated pipeline gas prices. The next chapter will discuss the geographical and sectoral pattern of gas consumption, and show that the Natural Gas Utilisation Policy and NOC strategy will have remarkable implications for gas consumption.

Chapter 6 Consuming Gas

6.1. Introduction

As noted, the Chinese government has released its official quantitative target in the current twentieth Five-year Plan (2011-2015) that the share of natural gas in the primary energy structure is increased to 10 percent by 2020. The previous two chapters have discussed the transitions in the networks of actors and institutions in the processes of gas acquisition and distribution. These are the twin processes of gas supplies, which form the material and spatial foundation for the increase in gas consumption. Based on the findings and observations from the previous chapters, this chapter investigates gas consumption sectorally and geographically. While the design of this dissertation owes a great deal to the GPN perspective, it should be acknowledged that this chapter, compared with the previous ones, has less tangible connections with the GPN framework, for two reasons. First, since this chapter will need to explore, though varying levels of depth due to data availability, virtually all gas-consuming sectors, from power generation to transport, it would be unrealistic (if not impossible) for a dissertation chapter to deal with the entire supply chain and all the different actors and institutions involved in each sector. Second, the GPN framework is criticised as too "productionist" in application, and it currently provides few conceptual tools for the analysis of the end-use consumption.

Perhaps the emphasis of GPN on spatial embeddedness and path dependency is most relevant to the analysis of consumption. These concepts serve to make sense of the obstacles to any energy transition. By "embeddedness" in this case, it means both the sunk costs of capital investment (represented by the built environment and the infrastructures), and the place-based cultures of consumption that surround certain energy technologies (Bridge et al. 2012). So the stronger the effect of "spatial lock-in" (Bridge et al. 2012, p.339), the more difficult it is for alternative energy transition to materialise. This concept of spatial embeddedness is especially relevant in the study of gas consumption: New gas production, import and distribution imply new infrastructures co-existent with other sunk costs; they do not necessarily compete with the oil pipeline or coal mine infrastructures that are already in place. But new gas consumption often requires the retrofitting of appliances and changes in cultures of consumption, which are slower and more difficult than the changes in the upstream and mid-stream.

The rest of the chapter is organised in the following way: Section 6.2 outlines the geographical patterns and sectoral trends of gas consumption, and discusses how government planning and pricing has significantly shaped them. Given the limited supplies of natural gas, the Chinese government has prioritised gas use for different sectors through administrative means, such as central approvals on investment, which have been very effective and reflected in the shift in the sectoral pattern. The chapter will then study each gas-consuming sector. Section 6.3 investigates the role of gas-fired power generation, explains why its importance remains severely limited in the fuel mix and geographical coverage, despite some growth. Section 6.4 acknowledges that industry remains the largest gas user and it recognises that industrial gas demand has not grown fast, despite the rapid increase in the total energy consumption of industry. Therefore it seeks to make sense of the stagnation in the importance of gas in industry via a sub-sectoral analysis. Section 6.5 looks into the role of gas as an alternative transport fuel, and argues that the transport sector will be the leading driver of gas demand in the decades to come. It also echoes the argument in the previous chapters that, since CNG/LNG prices are not as regulated as domestic pipeline gas prices, promoting natural gas vehicles (NGVs) is not only a national effort to reduce dependence on oil, but is more likely a self-help strategy of the NOCs to hedge the price risks imposed by the difference between regulated gas prices and market-based gas import prices. Section 6.6 analyses the residential energy transition, the rise of gaseous fuels (natural gas, LPG and coal gas), and how natural gas appears to be winning the competition.

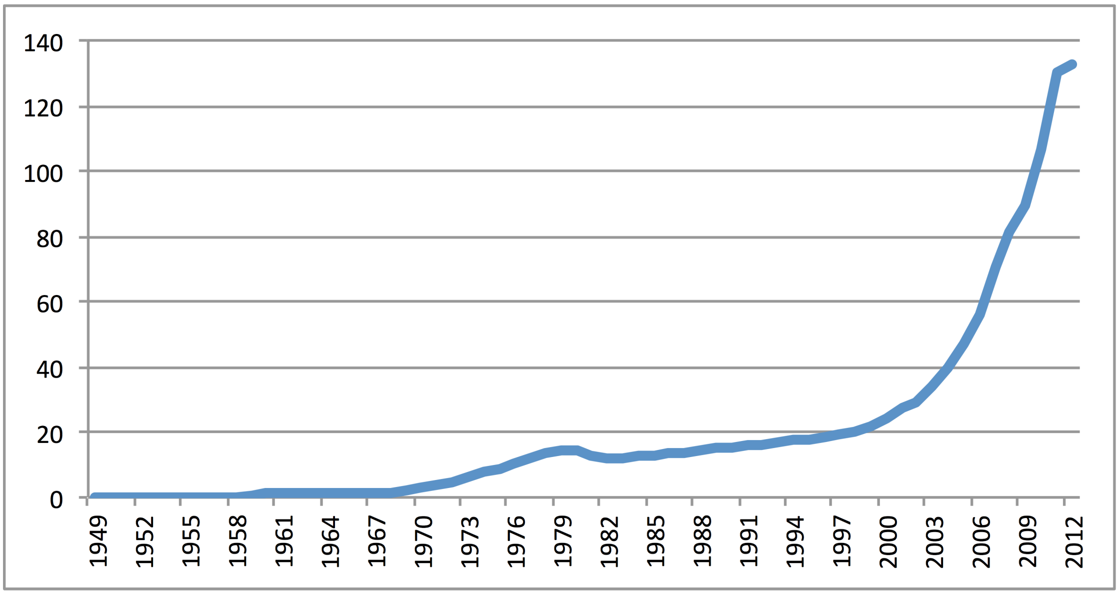
6.2. Pattern and Trends

6.2.1. Geographical Pattern

The use of natural gas in China reportedly dates back to about 3000 years ago (Li et al. 2011), although gas did not emerge as a more significant fuel for the country as a whole until the last decade. It took the country five decades to increase gas consumption from almost zero (0.007 bcm) in 1949 to 21 Bcm in 1999, but national gas demand rocketed from 25 Bcm in 2000 to 133 Bcm in 2012 (Figure 6.1). Per capita natural gas consumption displays a similar trend: per capita gas use edged up from 14 cubic metre /day to 17 cubic metre /day during 1980-1999, but surged from 19 cubic metre/day to 84 cubic metre /day during 2000-2011 (Figure 6.2), although it still significantly lags behind

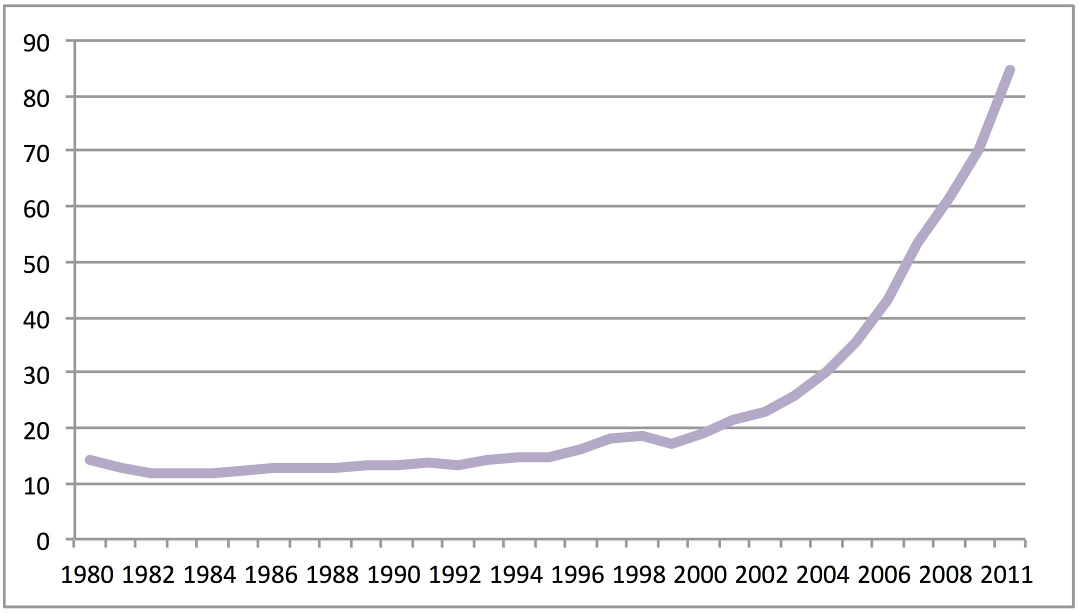
935 cubic metre /day in Germany, 1354 cm/day in the UK, 2177 cubic metre /day in the US and 3255 cubic metre /day in Russia (Eni 2012). During the last decade, national gas consumption has proliferated not only volumetrically but also geographically. In 2001 most provinces either did not consume gas at all or consumed lower than 1 Bcm of gas annually; only the gas-producing provinces (Xinjiang, Sichuan, Chongqing, Jilin, Heilongjiang) and the Capital (Beijing) consumed more than 2 Bcm (Figure 6.3). By 2011, however, almost all provinces used natural gas and several has emerged as significant gas-consuming provinces by international standard, including Sichuan (16 Bcm, comparable to Belgium's 16.6 Bcm or Poland's 15.7 Bcm in 2011), Jiangsu, Xinjiang and Guangdong (9-11 Bcm, comparable to Austria's 9.5 Bcm or Hungary's 10.4 Bcm), Shaanxi, Shanghai and Beijing (6-7 Bcm, comparable to Peru's 6.1 Bcm or Azerbaijan's 8.1 Bcm), Hainan, Shandong and Shanxi (5-6 Bcm, comparable to Denmark's 5 Bcm, Portugal's 5.1 Bcm, Isreal's 5.3 Bcm), as well as Fujian, Zhejiang, Liaoning, Inner Mongolia and Hubei (4 Bcm, comparable to New Zealand's 4.3 Bcm) (Figure 6.4) (BP 2013).

Figure 6.1 China's Natural Gas Consumption, 1949-2012 (Bcm)



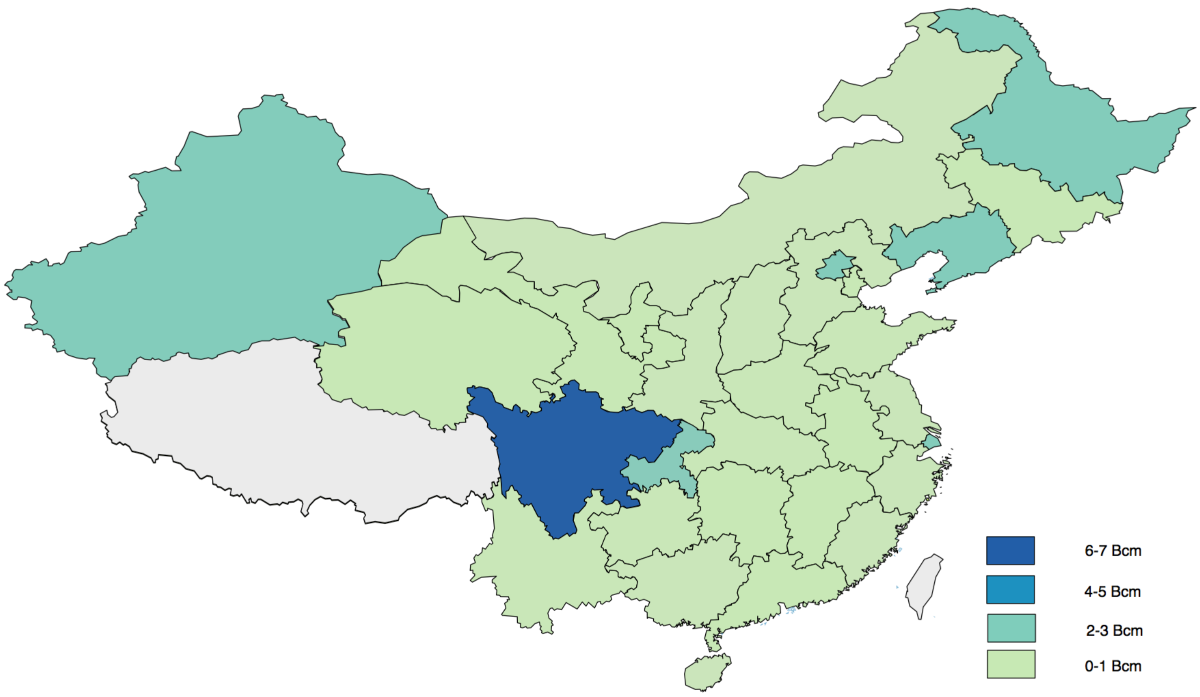
Source: CEIC (2014)

Figure 6.2 Natural Gas Consumption Per Capita, 1980-2011 (cubic metre)



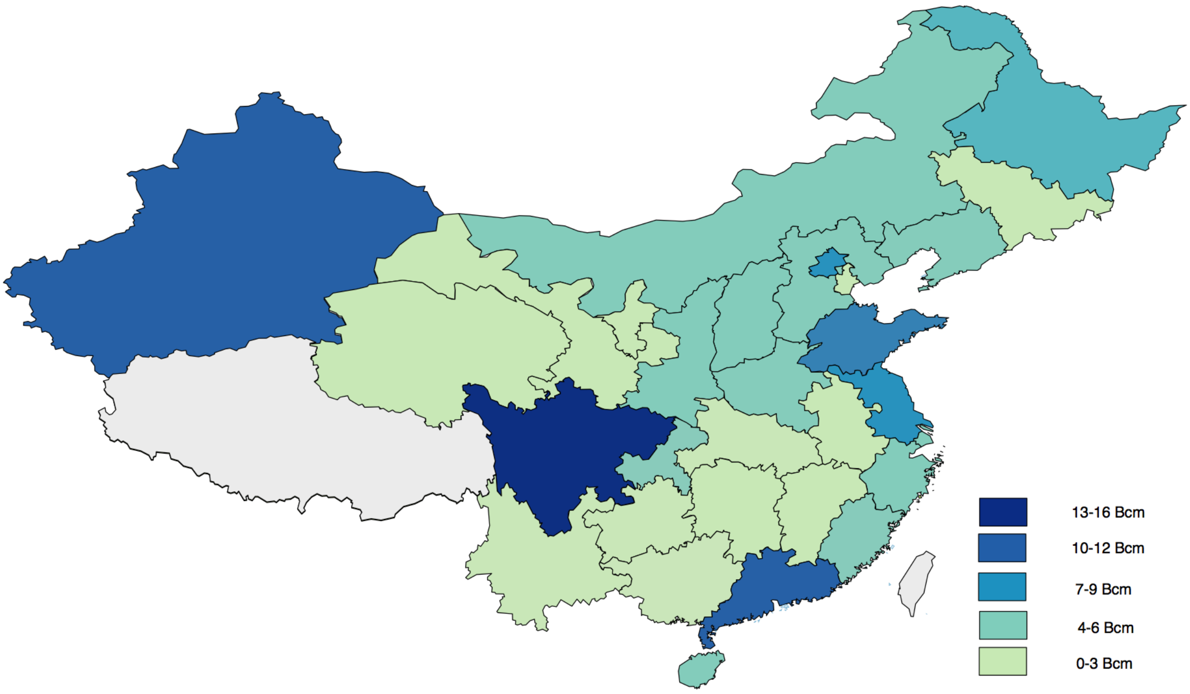
Source: CEIC (2014)

Figure 6.3 China's Natural Gas Consumption by Province, 2001



Source: Data from CEIC (2014)

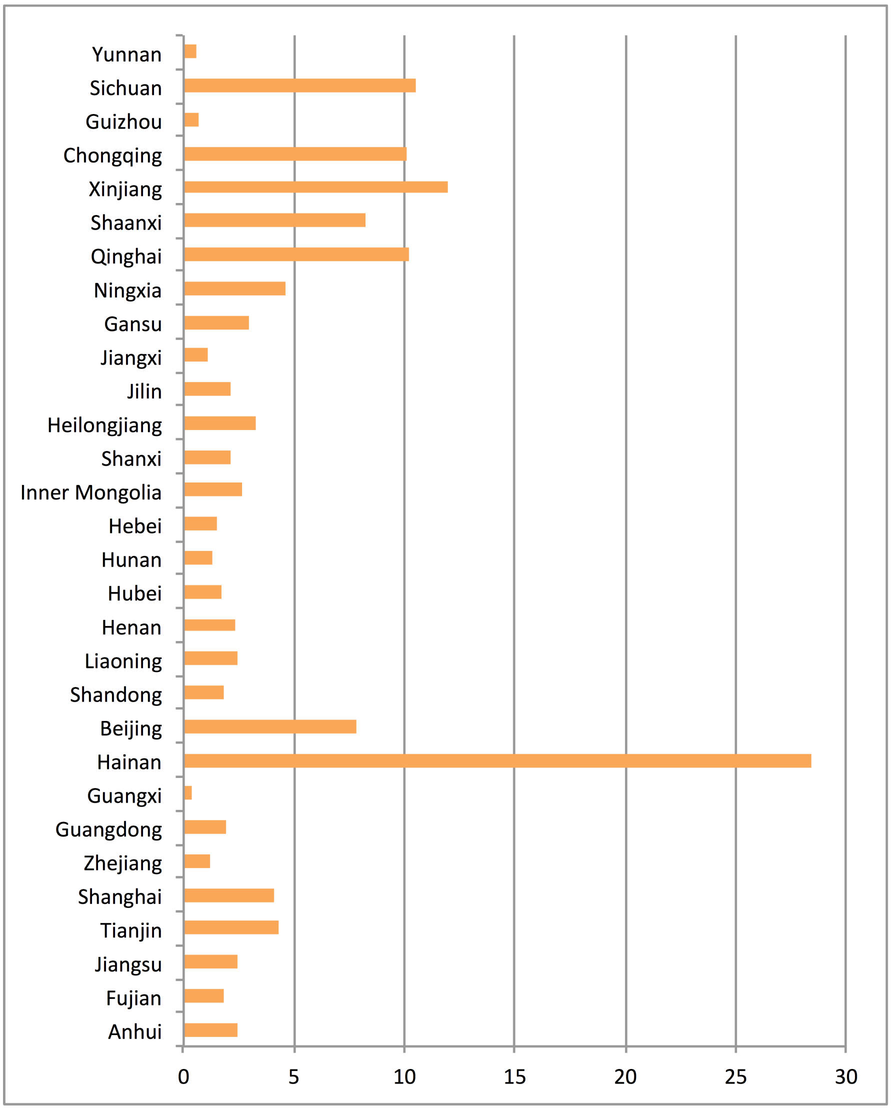
Figure 6.4 China's Natural Gas Consumption by Province, 2011



Source: Data from CEIC (2014)

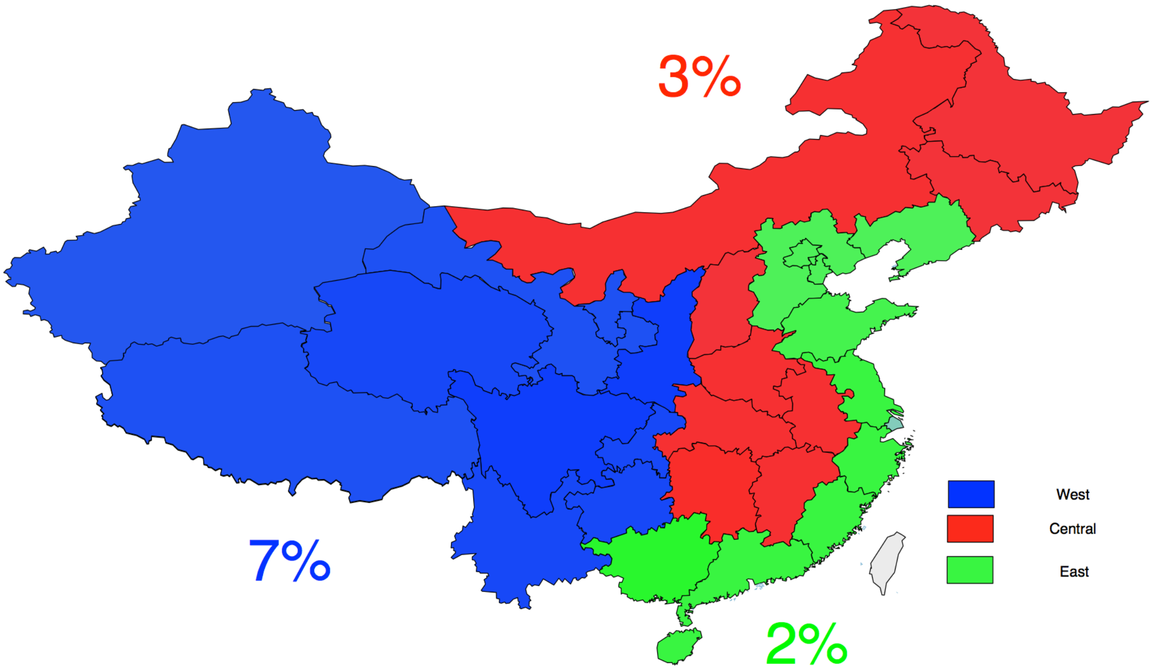
Although these emerging gas-consuming provinces can be considered as the driving forces of China's growth in natural gas consumption, gas actually remains a marginal fuel to the primary fuel mix of most of these provinces. Figure 6.5 displays the share of natural gas in each province's primary energy structure. It suggests that gas did not account for more than 5 percent in most provinces. Gas took up no more than 1 percent in the fuel mix of Yunnan, Guizhou, Guangxi and Zhejiang, because of either a lack of indigenous gas sources or a lack of pipeline penetration. Natural gas plays a significant role only in Hainan, accounting for 28 percent of its fuel mix, resulting from a small energy market and a relatively large gas supply from offshore southern China; however, since the province's energy demand accounted for only 0.2 percent of the national total, its gas consumption represented only 2 percent. If we look at the statistics on gas consumption using China's official policy region scheme (which loosely classifies China into the Eastern, Central and Western regions), we find that due to their richer gas endowment, natural gas is more popular in the Western China region, where gas accounted for 7 percent of the fuel mix, compared to 3 and 2 percent in the Central and Eastern China, respectively (Figure 6.6). Despite the lowest share of gas in its fuel mix, Eastern China, the national economic powerhouse, accounts for 47 percent of national energy demand in 2011; therefore, it consumed 38 percent of gas, higher than 21 percent of Central Asia, but still lower than 41 percent of Western China.

Figure 6.5 The Percentage of Natural Gas in Primary Fuel Mix, 2011



Source: CEIC (2014)

Figure 6.6 The Percentage of Natural Gas in Primary Fuel Mix by Official Policy Region, 2011



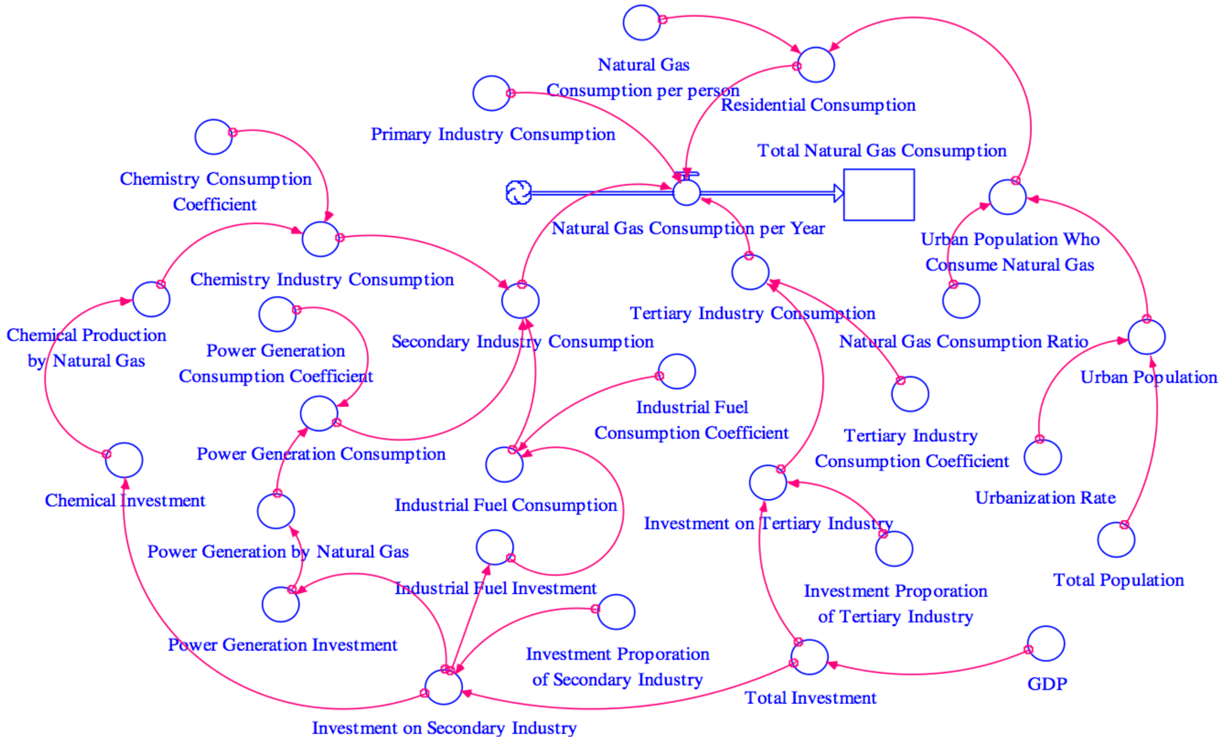
Source: Data from CEIC (2014)

6.2.2. Sectoral Trends

Central government policy requires natural gas to account for 10 percent of the country's primary fuel mix by 2020, but no consensus has been reached over whether such a target will be fulfilled or what the level of consumption required in 2020 should be. The widely circulated IEA study on China's natural gas industry (Higashi 2009) agreed with the government estimate at that time that China's gas demand would reach 250 Bcm by 2020 in order to realise 10 percent of fuel mix. The IEA's latest estimate of 307Bcm is higher (International Energy Agency 2013, p.3). (Paik 2012) summaries the 2020 estimate made by NOC, Chinese government and international energy institutes between 2004 and 2011 and the figures range widely from 200 Bcm to 300 Bcm, and the later the prediction was made, the larger the prediction tends to be, indicating that China's gas market grew faster than many analysts had expected. My fieldwork in 2013 reinforces the impression that even the industry leaders are uncertain about China's future demand for gas. An energy leader from NDRC shared with me his prediction that China's 2020 gas demand will reach 400 Bcm (Interview 20). His grounded his projection on the likely trend that natural gas vehicle (NGV) will proliferate rapidly to the extent that China might encounter a peak oil demand in the future (he did not specify what time in the future). A senior researcher at CNPC (Interview 9) completely rejected the figure from NRDC believing that China's demand growth will slow down as long as gas-fired power plants remain uncompetitive with coal-fired power plants. He claimed that China will have a surplus of gas supply equivalent to 60 Bcm by 2015 and 100 Bcm by 2020, resulting from the gap between contracted gas imports and slower than expected gas demand. He went on to warn that if the government found no way to significantly raise the use of gas in power generation by expanding its function from only peak-shaving to include base-load power supplies, the national gasification plan will fail. However my interviewee from Kunlun Gas rejected unequivocally his CNPC colleague's gloomy perspective and held that China will face gas shortages (Interview 13). A recent WoodMackenzie study also predicts that "Winter gas shortages will be exacerbated through to 2020 as seasonal demand growth in northern China increases at an annualised rate of approximately 16% per annum" (Wood Mackenzie 2013). These conflicting estimates by domestic and international energy authorities suggest the high uncertainty over gas demand growth.

This study does not attempt to project future gas demand in China. The long-term drivers of gas demand worldwide are "overall economic and population growth, environmental policy, energy efficiency, technological changes and prices for natural gas and substitute energy sources such as oil, coal and electricity" and short-term drivers as "weather, economic activity and changing relationships between coal and natural gas prices" (Commission 2012, p.7). So for any specific project, a great number of interdependent factors of different analytical order need to be quantified and modeled to estimate future gas demand. For example, Junchen Li from CNOOC research institute and Xiucheng Dong from PetroChina published an econometric study in 2011 that tried to forecast China's gas demand (Li et al. 2011). Figure 6.7 visualises their "system dynamics model for China's natural gas consumption" consisting of both aggregate and disaggregate factors. Despite their rigorous investigation, their 2011 projection on China's 2015 gas demand (at 133 Bcm) was quickly rejected by the actual 2012 consumption level. The projection failure does not mean that the model they used was not sophisticated and well articulated: but it does mean that (as the GPN approach would argue) institutional, technological and behavioural factors are unlikely to be accurately predicted.

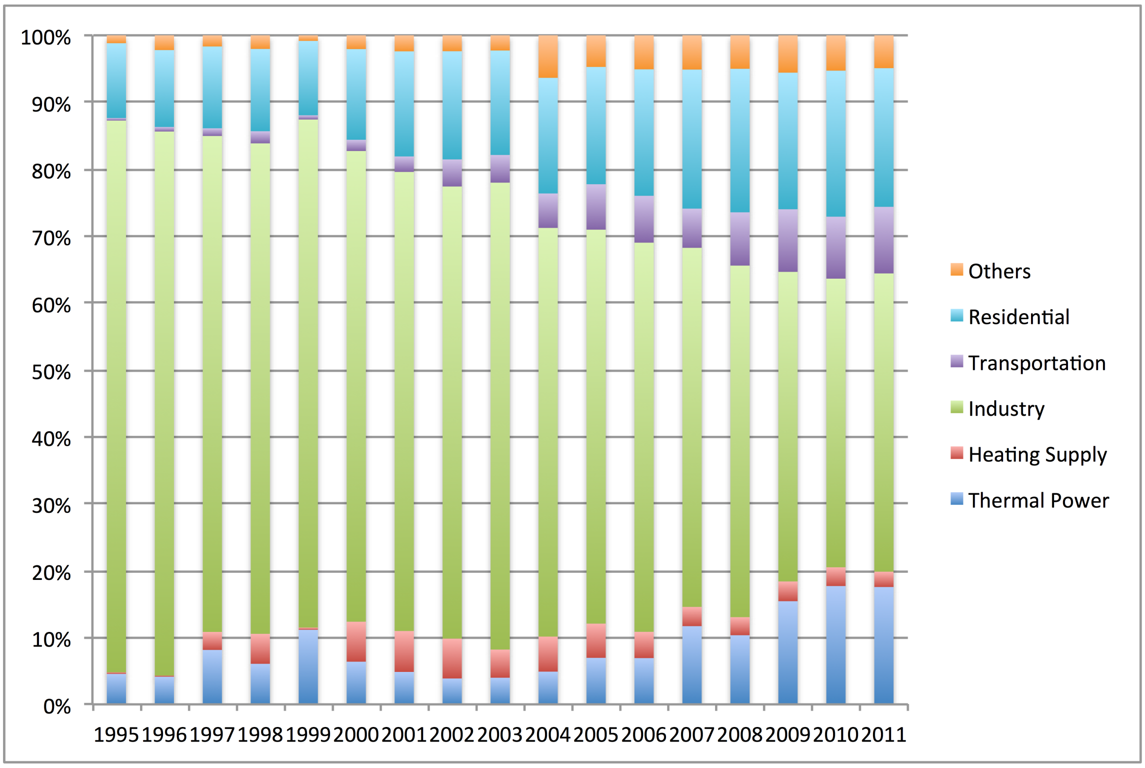
Figure 6.7 A Sample of a Forecast Model of China's Gas Consumption



Source: Li et al. (2011, p.1382)

The rest of the chapter investigates gas consumption in different economic sectors, including industrial, utilities (power generation and heating), transport, residential and commercial sectors. Each sector is subject to its own regulation, pricing mechanism, policy and other broader institutions. Figure 6.8 outlines the trend of natural gas consumption in China by sector. The more obvious trends are the increases in the share of power generation, residential and transport sectors as well as the reduction in the share of industrial sector, in spite of the absolute consumption growth in all sectors. Specifically the share of gas-fired power generation in total gas use increased remarkably from 4.6 percent in 1995 to 17.5 percent in 2011, and that of heating supply increased slightly from 0.2 percent to 2.3 percent. The share of industrial gas use shrank by half from 82.5 percent in 1995 to 44.6 percent, while the shares of the residential and transport sectors increased from 11.2 percent to 20.7 percent, and from 0.4 percent to 10 percent, respectively. It appears that the transport sector is set to overtake the residential sector to be the third largest gas consumer. “Others” in Figure 6.8 include everything else from commercial (e.g. office, hotel and restaurants), public buildings (e.g. public hospitals and schools), government, military and agriculture. Since the lack of detailed statistical breakdown and their relative insignificance (together accounting for less than 5 percent of total gas use in 2011), analysis of these gas uses is omitted from this chapter.

Figure 6.8 Sectoral Pattern of Natural Gas Consumption in China, 1995-2011



Source: CEIC (2014)

6.2.3. Planning and Pricing

China's sectoral pattern of gas consumption is highly subject to policy influence, regulation and differential pricing. The NDRC issued a Natural Gas Utilisation Policy in 2007, which categorised the priority of sectors and projects for natural gas use, and a new version in December 2012. Both are legal documents (Blumental et al. 2013). By comparing the differences between both versions, one can get a sense of the changing mentality of China's gas use governance. The 2007 Policy started classifying gas users in China into four categories — "Prioritised," "Allowed," "Restricted," and "Prohibited". Consumers within the "Prioritised" and "Allowed" categories could enjoy certain priority or preferential treatment in project approvals and gas pricing, as well as preferential assurance of gas supply, while users in the "Restricted" category and "Prohibited" category could encounter restrictions in those aspects. The 2012 version follows this catogorisation. Since the NDRC and its National Energy Administration (NEA) are in charge of approving energy projects across the country, and these documents or guidelines are believed to be influential. The "Prioritised" users under the 2007 Policy were more limited, which only include four types of gas use, i.e. urban residential, public service facilities, NGVs, and distributed combined heat and power generation. It is evident that the central government strived to ensure gas availability for the urban communities at a time when gas supply was limited. The 2012 Policy has increased the types of users included under the "Prioritised" category to 12 sub-categories. This change reflects government's increased confidence in securing gas supplies and determination in promoting gas use.

Table 6.1A contrasts the difference in the gas use preference in the power sector. Before December 2012, gas-fired power generation for peak-shaving was allowed in "important heavy-load regions" with abundant gas supply, but was restricted in "non-important heavy-load regions" (even though that region is rich in gas). Now, peak-shaving gas-fired power generation is allowed everywhere. Base-load gas-fired power supplies are always prohibited in the coal-rich regions, unless CBM is used; in fact, the 2012 policy for the first time mentions and prioritise CBM power generation. Combine heat and power generation is always prioritised for the benefit of the high energy efficiency.

Since the chemical industry used to be the major consumer of natural gas, the Policies list it separately from the industry in general (Table 6.1B). Both 2007 and 2012 Policies allowed gas-based hydrogen production, restricted new plants or products of gas-based synthetic ammonia production as well as acetylene, halomethane and other carbon chemistry projects, and prohibited any forms of gas-based methanol production. In the past, nitrogen-rich fertiliser production was allowed by new plants using the natural gas that is difficult to transport elsewhere, but it was restricted by using other natural gas; all new plants are now completely restricted. As for non-chemical industries, the 2012 version starts to prioritise industries (construction, machinery, textile, metallurgy and hydrogen) with interruptible service contracts, which mean that gas supply is flexible and can be interrupted so that industry-use gas can be channelled to other sectors when gas shortage takes place (Table 6.1C). The new version also allows, for the first time, new gas-powered projects in construction, machinery, textile and metallurgy, and gas consumption in industrial boilers in major urban centres. Fuel switches from coal and oil to gas remains allowed.

For the first time, the 2012 version has a section on transport gas demand and prioritises natural gas vehicle and vessels (Table 6.1D). Related to transport gas use, the section of city gas in the 2012 version now prioritises storage capacity and inland small-scale LNG facilities for peak-shaving, emergencies and storage (Table 7.1E). Gas-powered air conditioning is upgraded from being allowed to being prioritised. Gas use for urban cooking, water heating and public facilities remain prioritised and gas-fuelled household heating remains allowed.

Table 6.1A Comparison in Natural Gas Utilisation Policy 2007 and 2012 (Power Generation)

A: Prioritised; B: Allowed; C: Restricted; Prohibited

	2007	2012
General power generation	B/C	B
Base-load power generation in 13 major coal production centres (exception: CBM)	D	D
CBM power generation	—	A
Combined heat and power generation (70% efficiency or higher)	A	A

Table 6.1B Comparison in Natural Gas Utilisation Policy 2007 and 2012 (Chemical Industry)

	2007	2012
Hydrogen production	B	B
Synthetic ammonia plant expansion or new projects using natural gas	C	C
Acetylene, Halomethane and other carbon chemistry projects	C	C
New plants using natural gas in producing nitrogen-rich fertiliser	B/C	C
Methanol production	D	D
Fuel conversion from coal in methanol production	D	D

Table 6.1C Comparison in Natural Gas Utilisation Policy 2007 and 2012 (Non-Chemical Industry)

	2007	2012
Construction, machinery, textile and metallurgy companies with interruptible service contracts	B	A
Hydrogen producers with interruptible service contracts	—	A
Fuel switches from oil or LPG in the construction, machinery, textile and metallurgy sectors	B	B
Fuel switches from coal in the construction, machinery, textile and metallurgy sectors with good economic performance	B	B
Gas-fuelled new projects in the construction, machinery, textile and metallurgy sectors	—	B
Fuel switch for industrial boilers in major urban centres	—	B

Table 6.1D Comparison in Natural Gas Utilisation Policy 2007 and 2012 (Transport)

	2007	2012
Natural gas vehicle, especially bi-fuel vehicle and LNG vehicle	—	A
Natural gas-fuelled vessels, especially LNG (including dual-fuel)	—	A

Table 6.1E Comparison in Natural Gas Utilisation Policy 2007 and 2012 (City Gas)

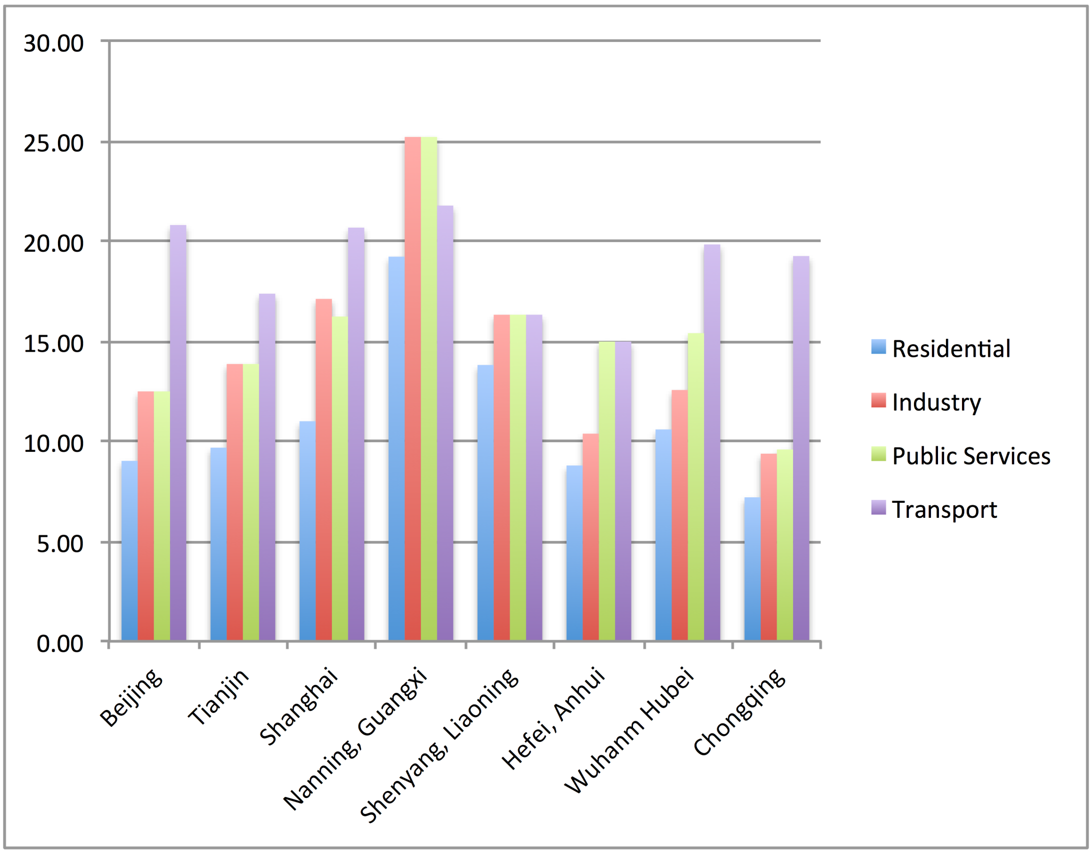
	2007	2012
Urban cooking and water heating	A	A
Urban public facilities	A	A
Central heating	A	A
Air conditioner	B	A
Household heating	B	B

Urban storage facilities for emergencies and peak-shaving	—	A
Small LNG facilities for peak-shaving and storage	—	A

Sources: Natural Gas Utilisation Policy 2007 and Natural Gas Utilisation Policy 2012

The Chinese government also shapes the sectoral pattern of gas consumption by implementing differential pricing, which reflects the objective of the Policies. China's end-use gas prices are not low; in fact, they are considered high in non-OECD countries. For example, end users in the Middle East and Africa, for instance, usually pay prices ranging from USD 1 to USD 4/MBtu (International Energy Agency 2012, p.20). Figure 6.9 displays the end-user gas prices in selected Chinese cities, ranging from 7 to 25 USD/MMBtu in 2011, where residential gas prices are the lowest in each city. This results from the central government's motive of encouraging residential gas use and the local governments' interest in protecting their residents (as mentioned in the previous chapter, increases of residential gas prices are done through public hearings on a local basis). This situation is the opposite of what can be observed in many OECD countries, where residential users usually pay higher prices than other users (excluding the specific social tariffs to protect the poorest) (International Energy Agency 2012), because of the higher handling costs for delivering gas to more fragmented small consumers (Interview 18). International Energy Agency (2012) regards this as a form of cross-subsidisation. While Wang & Lin (2014, p.548) explicitly state, "government pricing means energy subsidies", which are "one of government's policy tools for reali[s]ing economic, social and environmental objectives", the International Energy Agency (2012) trusts that this would distort the market's reaction to fuel prices. For example, some regional residential prices are reported to be even lower than the corresponding price of imports, creating losses along the gas value chain since the costs of transport, distribution and storage cannot be appropriately covered, which ultimately affect other sectors. Despite the lowest prices, residential gas demand grew more slowly than demand in the industrial, transport, and power sectors.

Figure 6.9 End-user Gas Prices in Selected Chinese Cities, 2011 (USD/MMBtu)



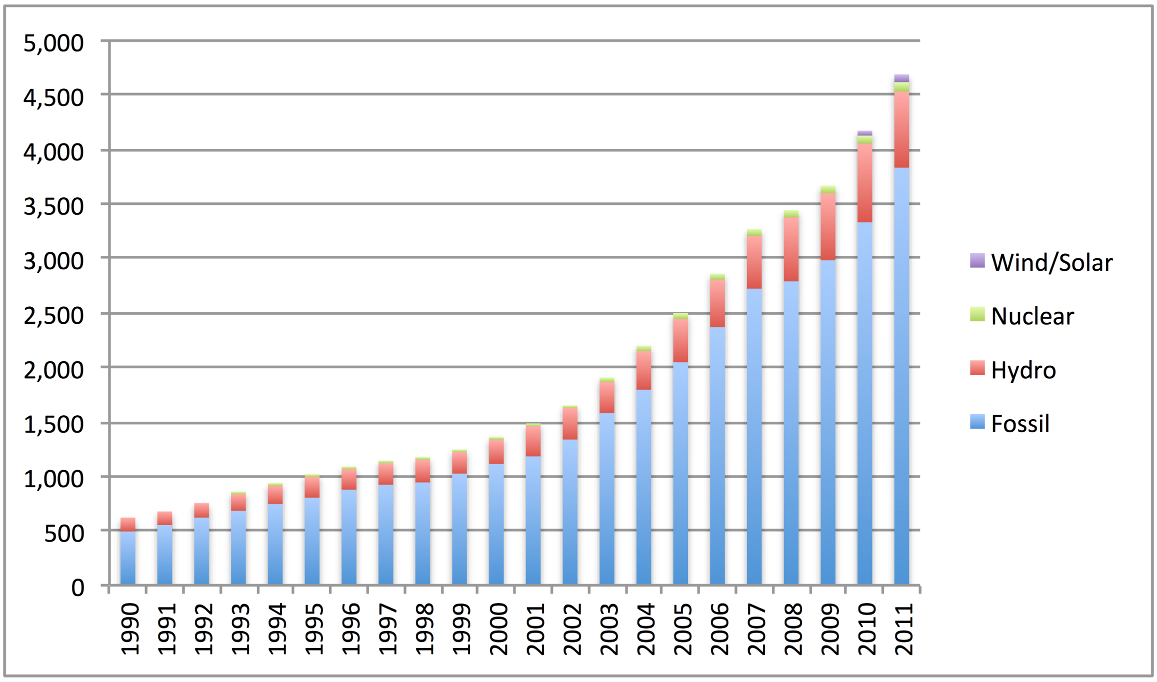
Source: International Energy Agency (2012, p.20)

6.3. Power Generation Gas Use

6.3.1. Constrained Role

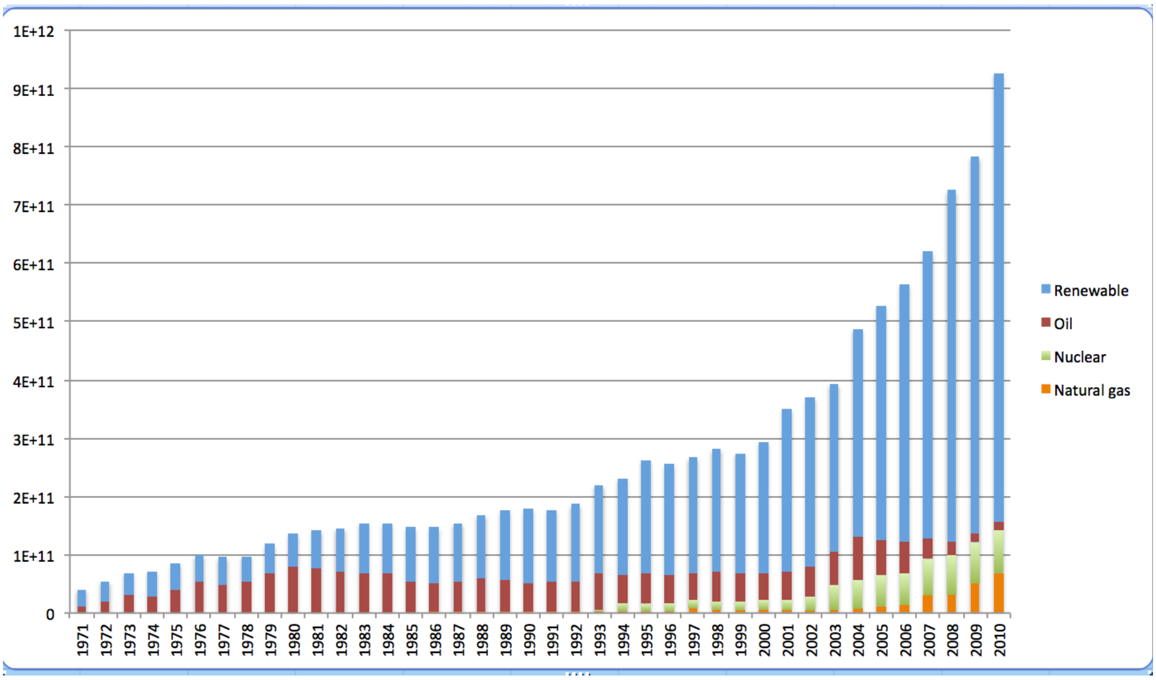
China is experiencing rapid electrification. In terms of end-use energy consumption (i.e. the form of energy that end-users consume), electricity accounted for almost 48.9 percent of the final energy structure in 2011, up from 25.5 percent in 1990 (CEIC 2014). This means that an increasing proportion of energy goes to the transformation sector, especially power plants. Despite the rapid increase in electricity demand, the composition of China's electricity outputs have changed relatively little in the last two decades (Figure 6.10). Thermal (fossil fuel) power generation is the dominant form (almost exclusively coal), although there has been a gradual increase in non-fossil sources. Figure 6.11 isolates the data of coal and has a clearer picture of gas-fried generation vis-a-vis other fuels. It suggests that the use of gas in power generation did increase since the mid-2000s, but the scale of growth is dwarfed by the pace of renewable power generation.

Figure 6.10 China's Electricity Outputs by Source, 1990-2011 (TWh)



Source: CEIC (2014)

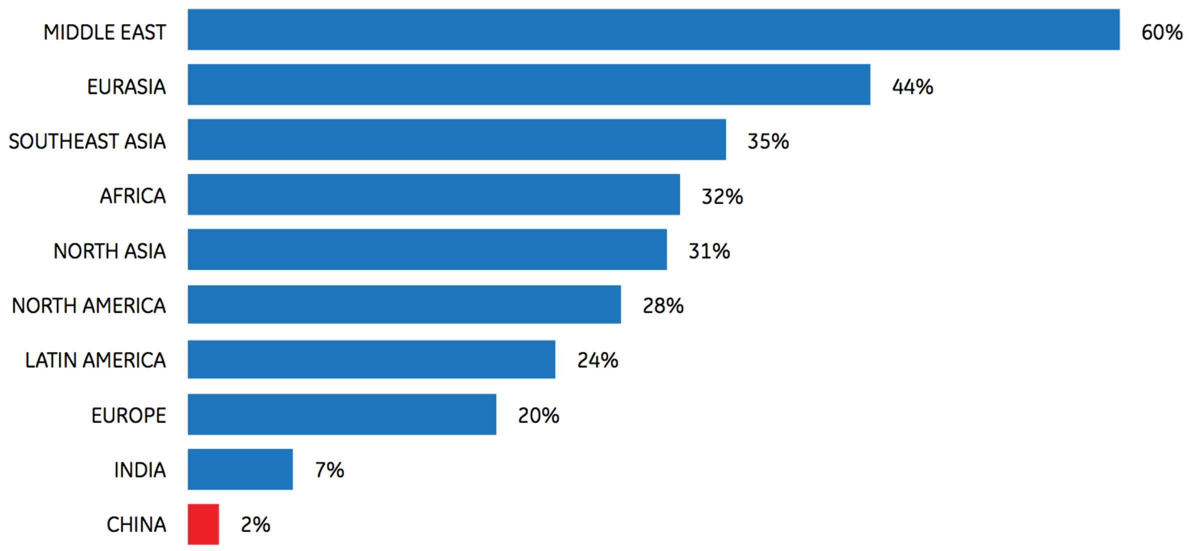
Figure 6.11 Electricity Production from Non-coal Sources in China, 1971-2010 (kWh/year)



Source: Leung et al. (2014)

International gas players, such as GE (Kushkina 2012, p.11), hold that "one of the important drivers of gas demand growth will be choices made in the power sector" in China, because the role of gas-fired generation is extremely limited by international standard and thus represents the greatest market potential. For example, the share of gas-fired power generation in total power generation in 2012 amounted to only 2 percent in China, which was even lower than India's 7 percent, North America's 28 percent and Eurasia's 44 percent (Figure 6.12).

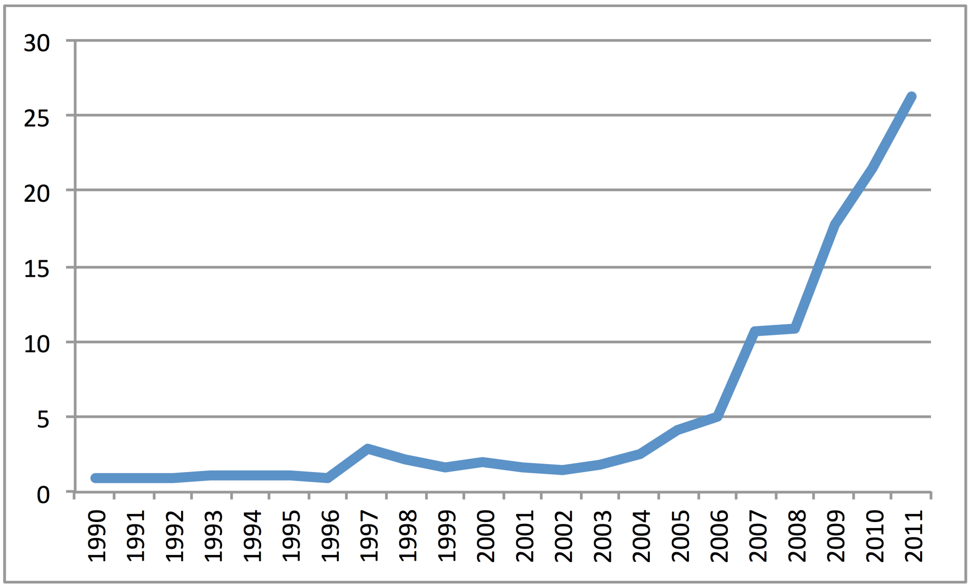
Figure 6.12 Share of Natural Gas in Power Generation, 2012



Note: North Asia includes Japan, Taiwan, and Korea. Southeast Asia excludes India
Source: Farina & Wang (2013, p.11)

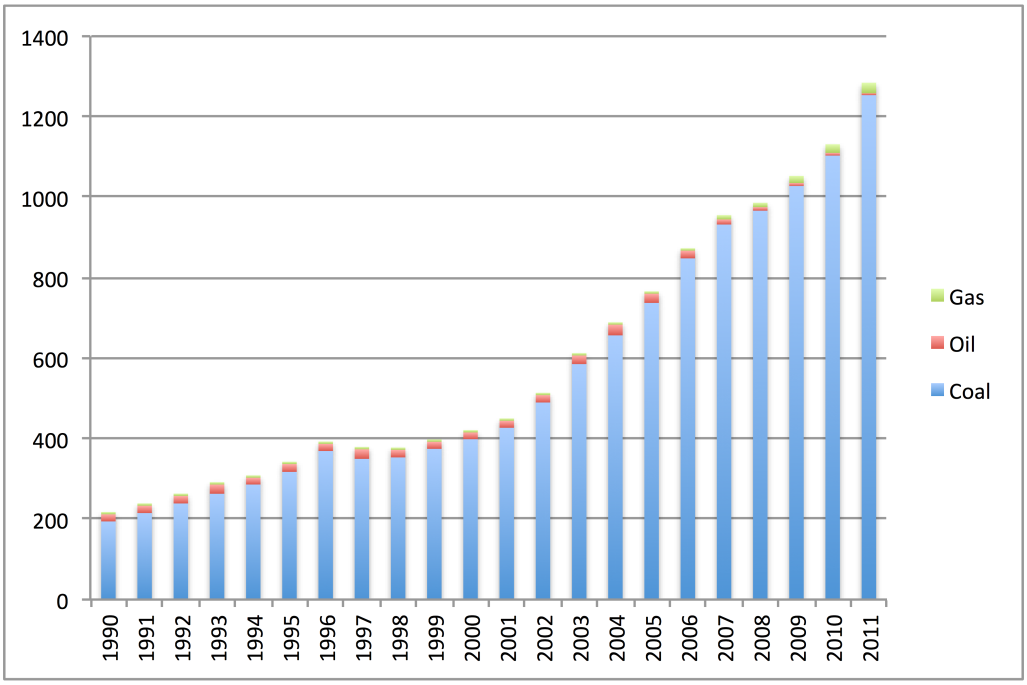
According to my interview with CNOOC Gas and Power Group (Interview 21), natural gas has been historically considered "too valuable to dump into power generation", as the power generated from either coal or natural gas has no functional difference. Such mentality was changed during the 11th Five-year Plan (2006-2010), when the new Hu administration proposed the idea of "scientific development", which stressed sustainable development and efficiency. Before 2007, the amount of gas for power generation fluctuated narrowly between 1-2 million tons of coal equivalent (Mtce) most of the time (Figure 6.13). The figure had risen to 11 Mtce in 2007 and jumped to 26 Mtce by 2011. However, despite the recent growth, the role of gas-fired power generation remains extremely constrained: the dominance of coal in the thermal power sector has in fact further strengthened, with the share rising from 91 percent in 1990 to 97 percent in 2011, while the share of gas edged up from less than 0.5 percent in 1990 to 2 percent in 2011 (Figure 6.14).

Figure 6.13 Natural Gas Inputs to Power Generation, 1990-2011 (Mtce)



Source: CEIC (2014)

Figure 6.14 China's Gross Fuel Inputs to Thermal Power Generation, 1990-2011 (Mtce)



Source: CEIC (2014)

6.3.2. Constrained Use

The fact that gas-fired power generation grew at the expense of oil-fired power generation largely reflects that the former is replacing the latter as an option for peak-shaving power supplies. Oil-fired power generation was popular in China before the 1990s, when the country was self-sufficient of oil and was a large oil exporter in Asia (Leung 2010). After China's becoming a globally significant net oil importer in the era of high oil prices, the role of oil (mainly diesel) for peak-shaving has been gradually replaced by natural gas. The economic advantage of gas over oil, short lead time of construction, and the short startup time of gas-fired power turbines (less than 30 minutes, compared with a few hours in the case of coal-fired turbines) make the form of power generation an economically sound and functionally convenient option for peak-shaving (Interview 22). On the other side of the coin, the limited role of gas-fired power generation results from the fact that practically no gas-fired turbines are used for base-load supplies. As mentioned in last section, gas (except CBM) is currently prohibited for base-load power generation in most coal-abundant regions. In addition, gas power plants occupy less land so they are appropriate for being located in load centres, which helps support distributed electricity generation in case of emergencies such as power grid failure. For example, China suffered severe freezing rain and snow disaster in early 2008 and nearly all the West-to-East power transmission was disrupted. Distributed gas turbine power plants proximate to load center, however, were still committed to emergency power supply and provided protection, mitigating the threat of large-scale blackout. Given its contribution to domestic energy supply chain security and high efficiency, the development of distributed generation powered by gas is expected to be a priority and the cogeneration of cooling, heating and power will become the essential choice (Higashi 2009).

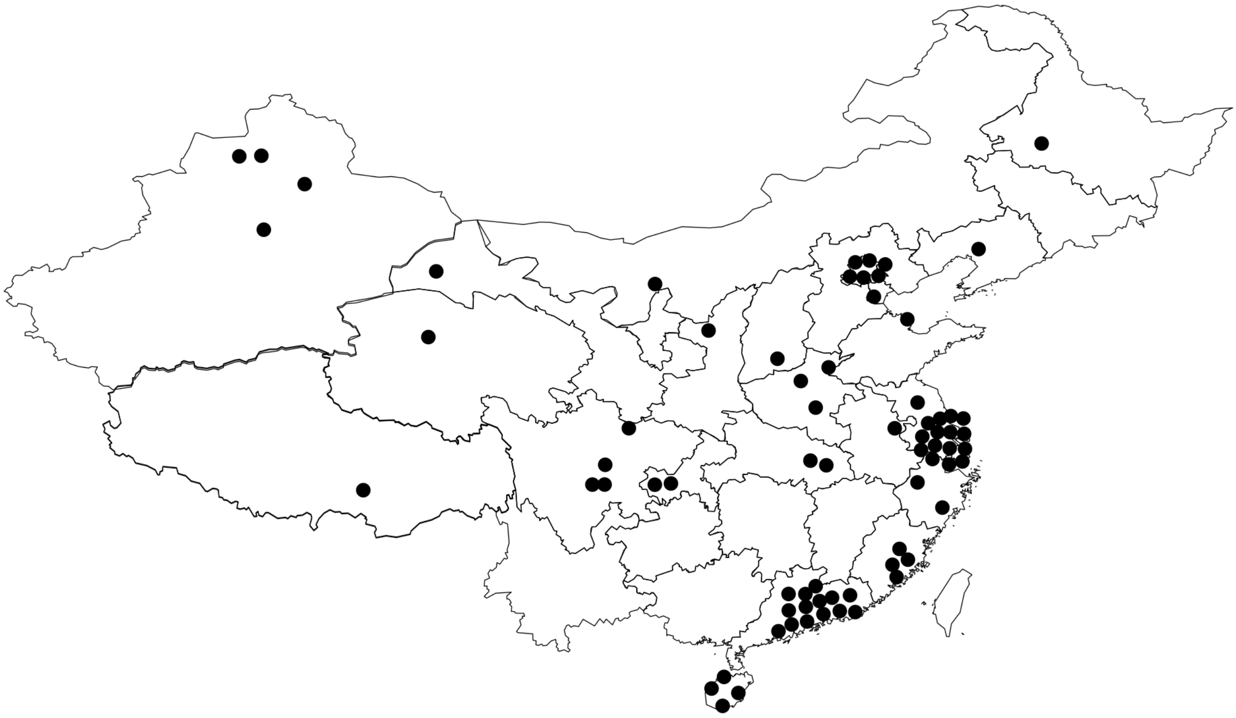
Another often overlooked situation is that gas turbines does not currently back up renewable energies in China. Two reasons are often cited for making gas power generation a partner to the renewables. First, gas power generation is often applauded for providing low-carbon, economical "spinning reserve" to intermittent renewable energies. Second, natural gas and renewable energy investment profiles are complementary: Renewable energies typically have higher up-front capital requirements and low operational costs, while natural gas generation has a low initial cost but high fuel-related operational costs (Natural Resources Defense Council 2012). It is, however, not the case in China. First, if the renewable energies are located in the above-mentioned coal-rich regions, gas cannot be called for. Second, providing back-up reserve means that the gas turbines concerned need to be idle the whole day, making it too costly to be feasible (Interview 22). Third, China's gas supplies are seasonally insufficient, in part because of the very low ratio of gas storage to gas use. My informant from NDRC stated that since China's pricing is regulated and costs are less transferable to the downstream market, the upstream and midstream players, i.e. NOCs, are not motivated to invest in gas storage capacity. The ratio is now only 2 percent in 2012, while the NDRC believed that the figure should be increased to 18 percent in order to establish a secure supply chain of gas.

As a result, renewable power generation is backed up by coal in China, as gas generation is not sufficiently available but national planners still request blindly installation of renewable energy infrastructure. In Gansu, China, for example, the local government installed 12,700 megawatts (MW) of wind turbines, but along those turbines, it also installed 9,200 MW of new coal-fired generating capacity for use when the wind is sufficiently blowing. That newly installed capacity of coal-fried generation is as large as the entire generating capacity of Hungary. To make matters worse, coal-fired power plant, unlike gas-fired power plant, are designed to supply continuous, base-load power and cannot be turned on and off quickly when needed (as it takes much longer time to generate steam). It implies that the coal-fired power generators in Gansu will need to operate continuously to ensure the safety of grid, no matter will they actually dispatch electricity to the grid or not (Bryce 2011).

6.3.3. Constrained Geography

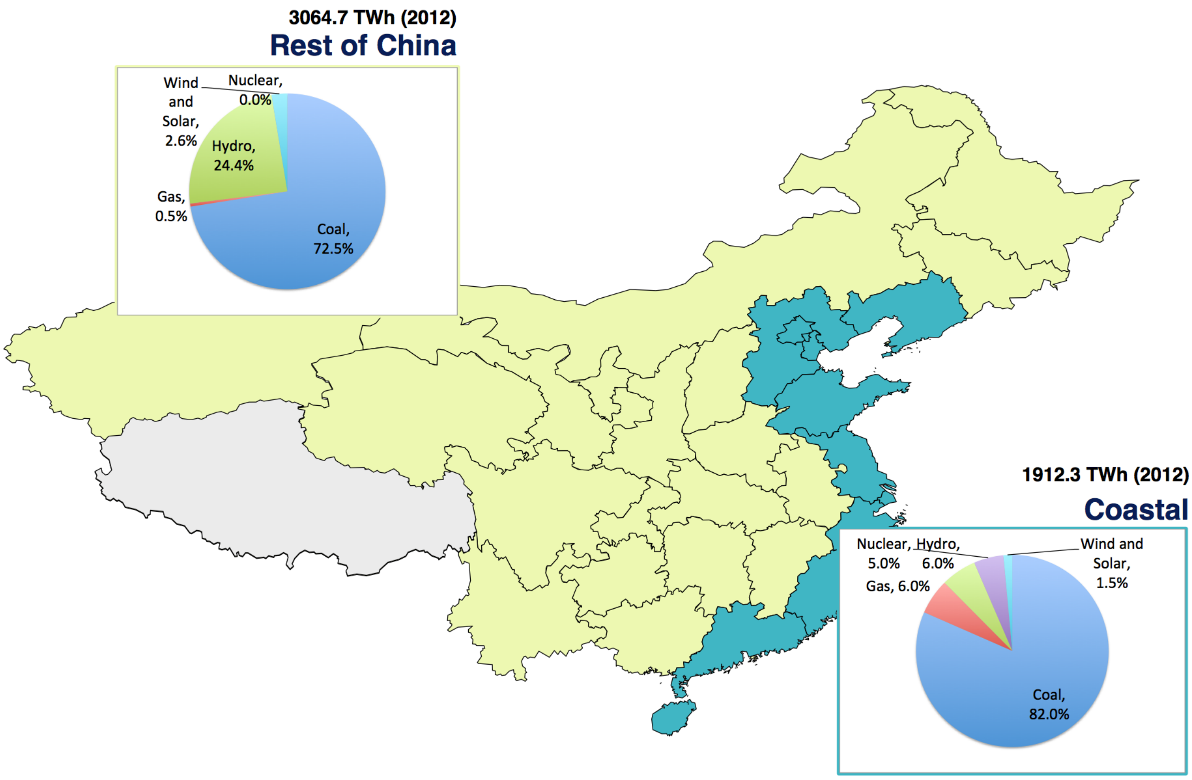
Moreover, gas-fired power generation is largely a coastal phenomenon. Figure 6.15 displays the geographical distribution of gas-fired power plants in China, and they are concentrated in the coastal region. 6 percent of total power outputs came from gas power generation in the coastal region, but only 0.5 percent in the rest of China (Figure 6.16). A number of reasons can explain such a remarkable geographical difference. First, the coastal region is the most economically developed area and thus possesses higher affordability of the more costly gas-fired generation. Second, residents in the more developed provinces usually have higher priority of city's air quality over economic growth, and local governments often impose restrictive emission policies on power companies. For example, Beijing city government recently announced that it will abolish coal-fired power plants by the end of 2014 by switching to gas-fired plants (XinHua News 2013). Third, during the planning phase of a new LNG receiving terminal project, LNG demand must be secured and booked before the launch of the project. To the LNG buyers, gas power plants serve as an important, bulk and stable demand, constituting a hedging strategy - during times of unexpected low demand, the buyers can channel it to the plants, mitigating the volume risk of "take-or-pay" clause in the LNG contracts (Zhang 2009).

Figure 6.15 Location of Operating Gas-fired Power Plants, 2012



Source: Data from IHS CERA (2013)

Figure 6.16 Regional Power Outputs by Source, 2012



Source: Data from IHS CERA (2013)

6.3.4. Key Challenges

Many reasons that are common to the constrained application of gas in other sectors are also limiting the role of gas in China's power generation, including gas supply shortage and lack of gas pipeline and storage. The key reason specific to the power sector, however, is the price disadvantage of gas compared with coal (whereas in other sectors, gas compete with oil products such as LPG, manufactured gas and electricity) (Farina & Wang 2013). Since the externalities of burning coal, such as carbon emissions and air pollution, are not factored in, coal prices are lower than gas. In general, fuel expenses per kWh for coal are about 50 percent cheaper than gas (U.S. Environmental Protection Agency 2012, p.105). However the central government has reformed electricity pricing by linking electricity prices to coal prices. The measure allows for an adjustment of the electricity price if the coal price rises by more than 5% during a six-month period, transferring 70 percent of the cost change to the end-users. However, those adjustments have not sufficiently changed the competitiveness of natural gas so far(Higashi 2009, p.15).

Gas-fired power generation lies at the intersection of two supply chains: the gas and power sectors (Figure 6.17), and the behaviors of the power and grid companies largely determine the actual use of gas as a power fuel. For example, on 2 August 2007, the NDRC issued the Energy Saving Power Generation Dispatching Measures (ESPGD) (trial), which requested that all types of electricity are dispatched in the following order (Dong et al. 2012):

i. wind power, solar power, ocean power, hydropower and other renewable energy generators without regulating ability;

ii. hydropower, biomass power, geothermal power and other renewable energy generators with regulating ability, and garbage power generators which meet the requirements of environmental protection;

iii. nuclear power generators;

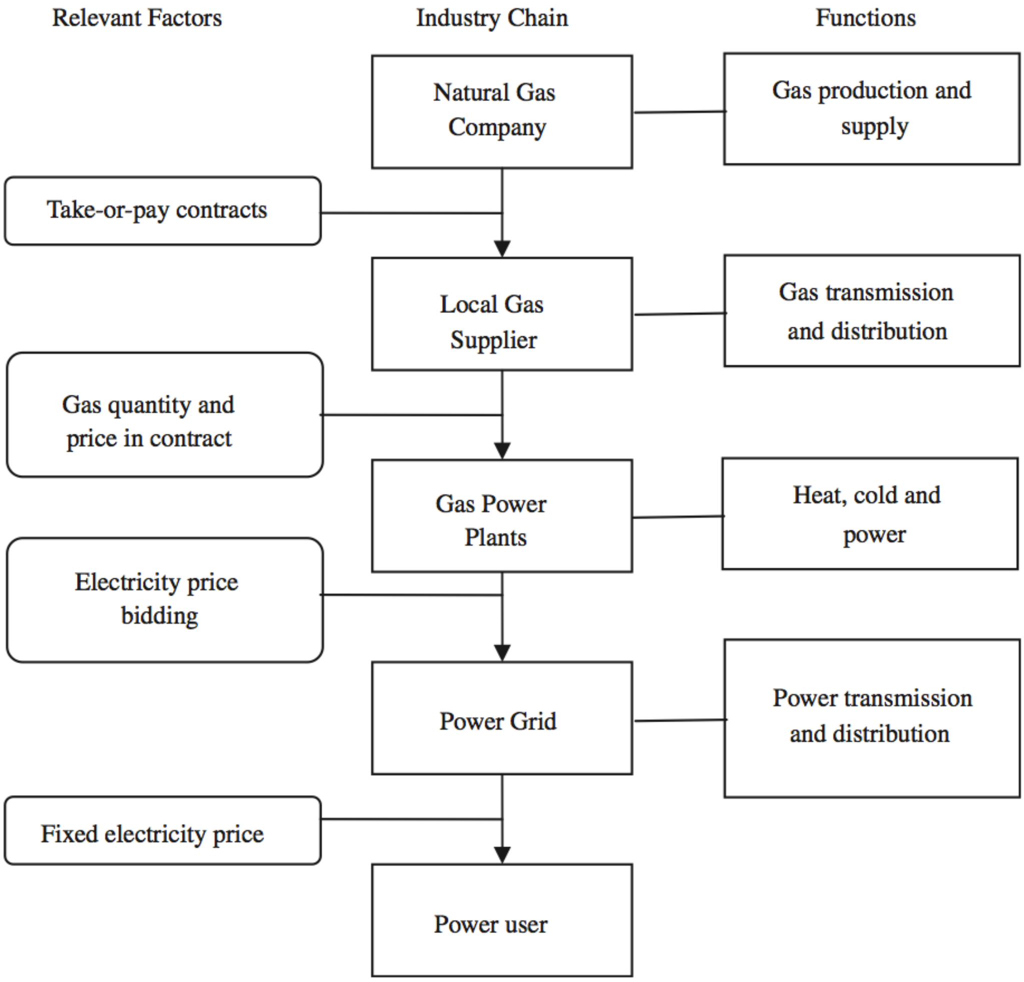
iv. coal-fired combined heat and power generation (CHP) by means of "with heat to determine electricity", and other comprehensive power generation units using non-coal resources, such as by-product of heat, gas, and pressure, coal gangue, washed coal, coal bed methane, etc;

v. natural gas and coal gasification generators;

vi. other coal-fired generators; and

vii. oil-fired generators.

Figure 6.17 The Gas-Power Supply Chains in China



Source: Dong et al. (2012, p.211)

On paper, natural gas power generators have higher priority being dispatched than conventional coal-fired ones; however, in practice, the ESPGD issued by the central government is not strictly followed in the local areas (Dong et al. 2012). For example, power grid enterprises do not prefer the wind power, solar power and other renewable power generation are not preferentially dispatched, as they pose threats to the grid security and stability. Similarly, the power grid enterprises are not always willing to purchase gas power, as its feed-in tariffs are considerably higher than coal-fired power. According to the interview with CNOOC Gas and Power (Interview 21), the on-grid power price of gas-fired plants is set by the central government on a plant-by-plant basis, and is approved before the plant is built. Generally, the on-grid price takes into account the operation costs, including fuel cost, and is the price at which power companies sell electricity to grid companies. However, the end-user tariff, especially the tariff for the households, remains constant for a relatively long period until the adjustment is approved by the government after public hearing. As a result, the gird companies cannot pass on the higher on-grid cost to the end-users. The losses generated are covered by government subsidies.

Although gas power plants can pass the contracted gas costs to the power grid companies, they face losses in two situations. First, when the power grid enterprises are not always motivated to purchase the power generated by gas power plants, the latter cannot predict their monthly, quarterly or annual gas sales, exposing themselves to the risk imposed by the “take-or-pay” clause in the gas supply contracts. This means that gas power plants need to pay for the gas they promised to buy even though they cannot use it (Dong et al. 2012). Second, if the gas power demand is stronger than the plants predicted, they run short of gas. To fulfill the supply contracts, the power plants need to buy gas on the spot LNG market, either domestic or international, at higher costs. This usually happens during seasonal demand peaks.

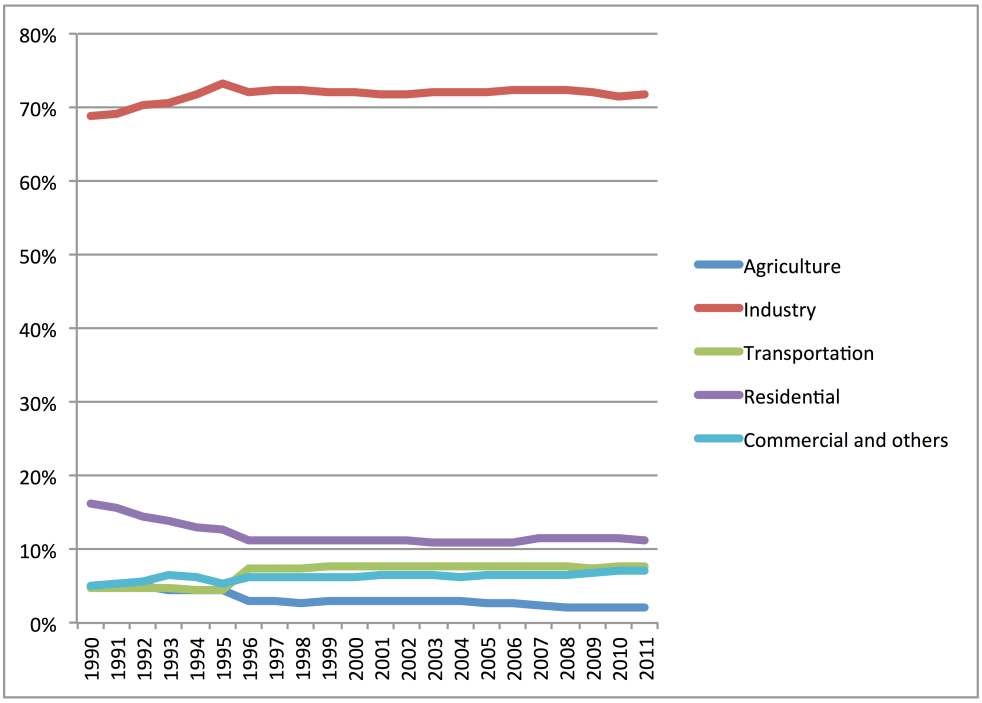
The reasons for power companies to invest in gas generation are complicated and beyond pure short-time commercial consideration. An informant from Towngas China revealed his insider perspective (Interview 16): the power plants now operate gas generation mainly for four reasons. First, as said, gas power plants’ baseload demand for gas provides demand security to LNG project. Since prices in the early LNG contracts are low, especially the Guangdong LNG case, the power fuelled by this cheaper gas is competitive. Second, they do so to diversify and decarbonise their generation mix in order to fulfil the environmental requirements of the local governments. Third, they foresee that the on-grid and end-user prices of gas power will be increased gradually in the future, and they are willing to suffer some losses in return for a larger share in a growing market. Fourth, a power company is often only one part of an enterprise that is either vertically or horizontally integrated. Satisfying the local officials’ requirements not only builds trusts between the enterprise and the local political leaders, but the non-power arm of the whole enterprise (e.g. Beijing Gas is wholly owned by Beijing Enterprise, which runs a wide range of other businesses) could also benefit from more favourable policies put forward by the local leaders in return.

6.4. Industrial Gas Use

6.4.1. Stagnation

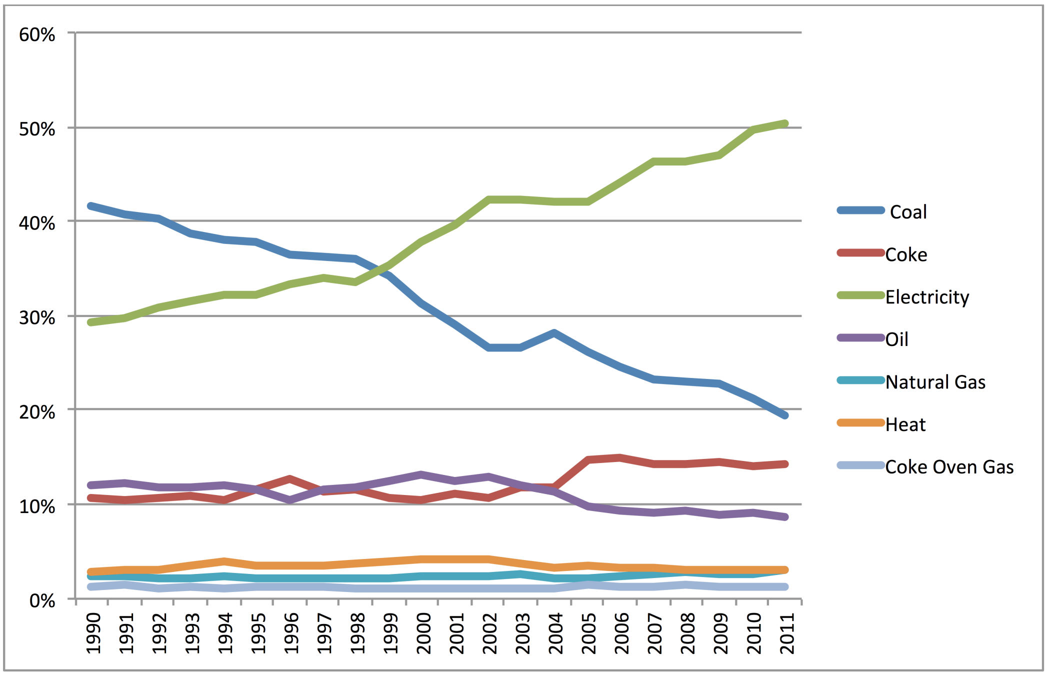
Given its significance to the economy and energy intensive nature, the industrial sector is the single largest energy consumer in China, with its share in final energy demand constantly staying at 72 percent since 1994 (Figure 6.18). This sector remains the largest gas consumer; however, since gas has remained a marginal fuel in total industrial energy use, the share of industrial gas demand in the total end-use consumption (energy statistics list the gas consumed by power plant separately and does not count it as "end-use") dropped from 85 percent in 1991 to 56 percent in 2011. Figure 6.19 shows the remarkable electrification of the sector (from 29 percent in 1990 to 50 percent in 2011) and the correspondent reduction in coal share (from 42 percent to 19 percent). Natural gas, on the other hand, remains a marginal fuel, taking up only 2-3 percent throughout 1990-2011. Geographically, only six provinces consumed more than 3 Bcm gas as an industrial fuel in 2011, including Sichuan (9 Bcm), Xinjiang (7 Bcm), Jiangsu (4 Bcm), Liaoning (4 Bcm), Hainan (4 Bcm) and Chongqing (4 Bcm) (Figure 6.20). The marginality of gas in the industrial fuel mix has less to do with fuel cost; on the contrary, gas price is relatively competitive. For example, the national average gas prices in 2011 was $13/MMBtu, which was around a 50 percent discount to LPG, and a 60 percent discount to diesel and gasoline. The fuel prices for industrial users of coal gas, fuel oil, coal, LPG, and gas in four major regions show that gas is very competitive against coal gas, fuel oil, and LPG (Figure 6.21).

Figure 6.18 Percentage of End-use Energy Consumption by Sector, 1990-2011



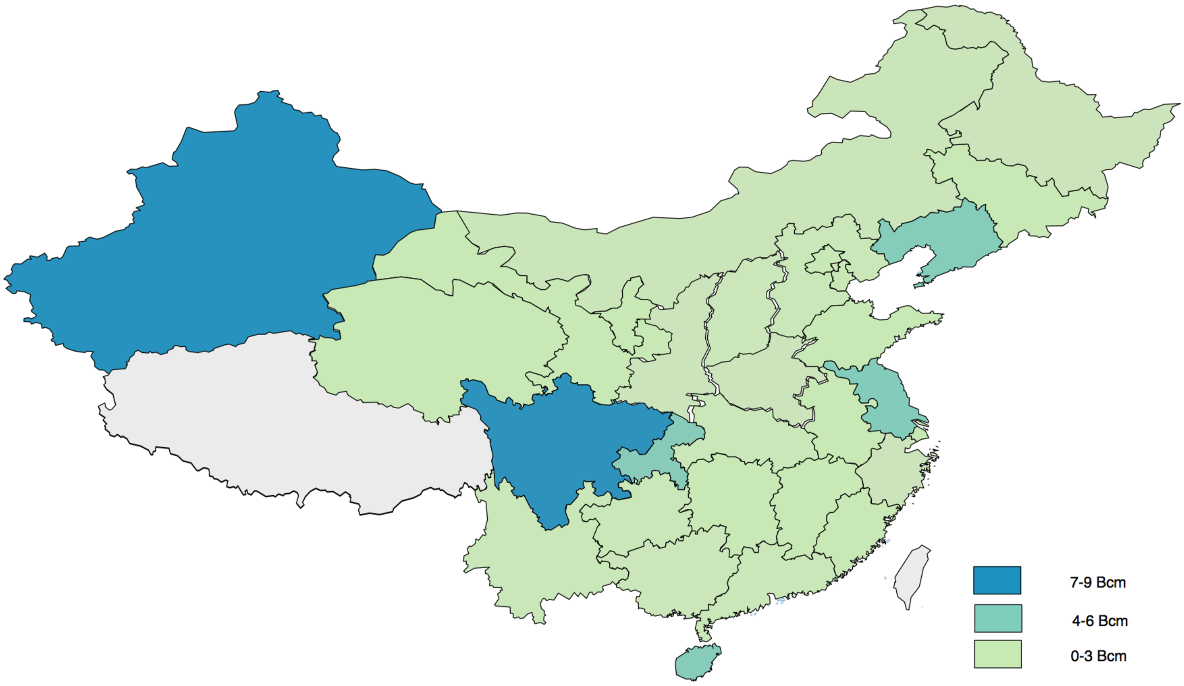
Source: CEIC (2014)

Figure 6.19 Industrial Fuel Mix, 1990-2011



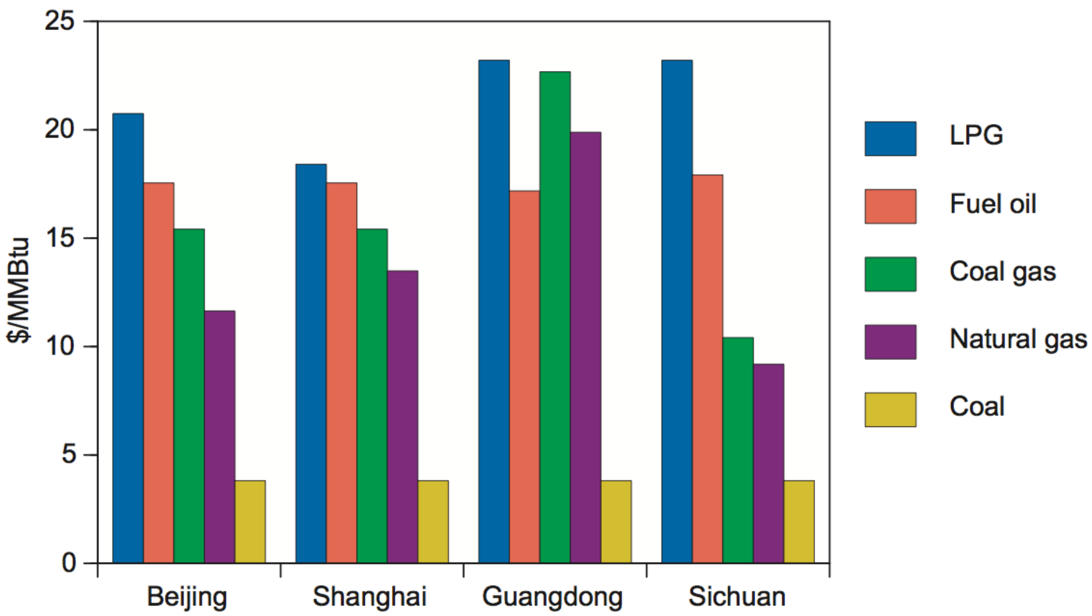
Source: CEIC (2014)

Figure 6.20 Industrial Gas Demand by Province, 2011



Source: CEIC (2014)

Figure 6.21 Comparison of Fuel Price for Industrial Users across Selected Regions, 2011

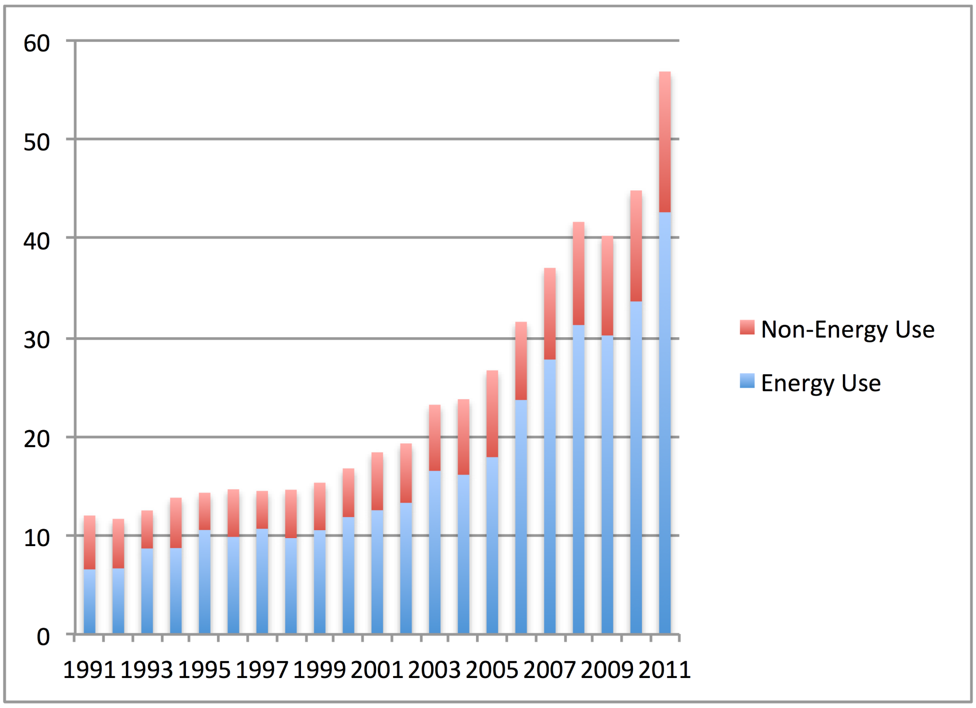


Source: Chen (2012, p.323)

6.4.2. Sub-sector Analysis

The small role of gas results from the fact that natural gas is often not an essential input to many sub-sectors of the industry. Natural gas is used as both a raw material (non-energy use) and as a source of heat. In the former case, natural gas is an ingredient used to manufacture fertiliser, antifreeze, plastics, pharmaceuticals and fabrics and to manufacture a wide range of chemicals such as ammonia, methanol, butane, ethane, propane and acetic acid. Both oil and natural gas are hydrocarbons and can be used as chemical and petrochemical feedstock; however, since gas is cheaper, chemical factories often adopt gas instead of only oil wherever supplies are available. Since the chemical industry is constrained by the state gas use policy, as stated above, and the growth in non-chemical gas use, the share of gas use as a raw material dropped from 45 percent in 1991 to 25 percent in 2011 (Figure 6.22). Many manufacturing processes require heat to melt, dry, bake or glaze a product. Natural gas is used as a heat source in making non-metallic materials, such as glass, steel, cement, bricks and many other commodities. Since gas is more expensive than coal, a factory adopts gas instead of coal because of three major reasons. First, the local environmental rules demand that the factory improve energy efficiency and lower its ecological footprint. In this case, the factory switches from coal to either gas or electricity. Second, the processes of some industries have to consume gaseous fuels, including glass, ceramics, textile and medicine. For example, the supplies of Eastern Guangdong LNG terminal, owned and run by CNOOC, are mainly contracted to the ceramics factories in the region (Interviews 21 & 25). Third, the use of natural gas in industries such as metal and non-metallic materials can improve the quality of the products because of the more intense and concentrated heat gas can release (Tian & Lin 2009).

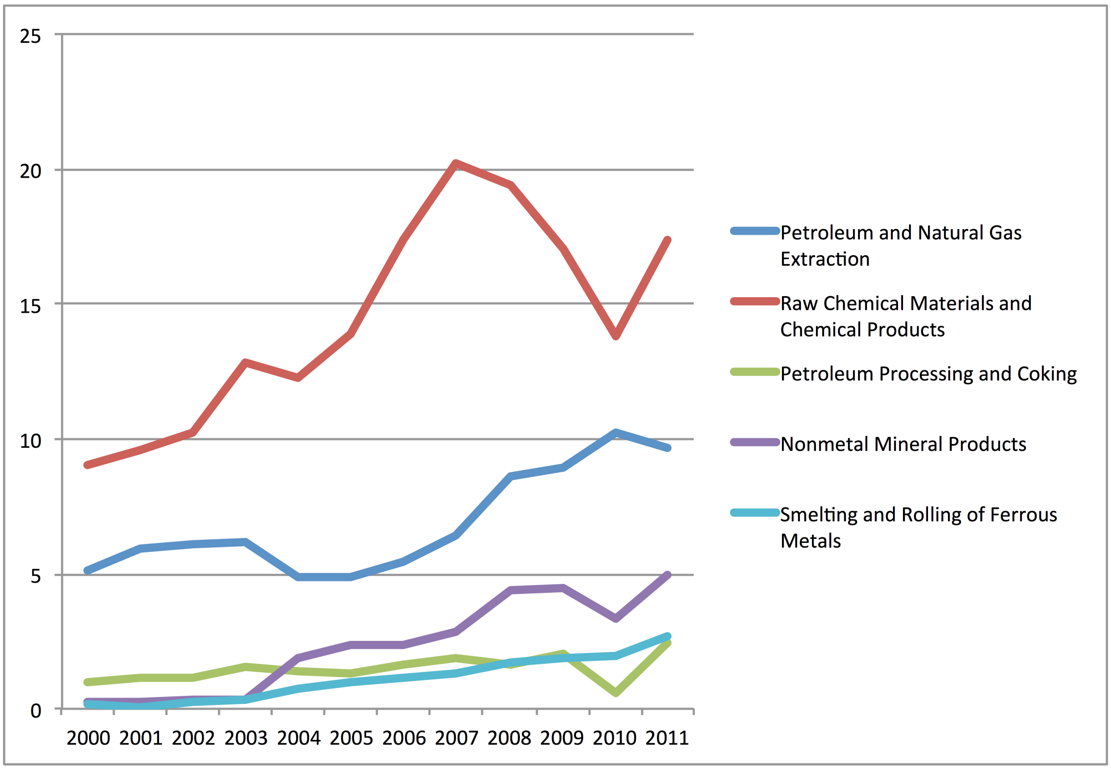
Figure 6.22 Industrial Gas Use by Type, 1991-2011 (Bcm)



Source: CEIC (2014)

Traditionally the use of gas was confined to the chemical industry: in 1990 the chemical industry accounted for about 50 percent of industrial gas use in 1990, and the oil and gas extraction sector consumed 30 percent (CEIC 2014). The chemical gas use is robust because the state has a subsidy policy towards fertiliser manufacturing in order to reduce the production costs of farmers. As a result, the gas used for making chemical fertiliser is priced lower than other industrial gas use. This often results in overproduction of chemical fertiliser. By 2011 the chemical industry represented 45 percent of industrial gas use, oil and gas extraction had declined to 21 percent, and significant other users had emerged, including ferrous metal, non-metallic mineral, and petroleum processing (Figure 6.23). Nonetheless, the further development of an industrial market for gas remains limited, as these sub-sectors already accounted for more than 80 percent of total industrial gas use in 2011. Amid the overproduction of some chemical and petrochemical plants using cheap gas and the national gas shortage, the government has taken a more restrictive stance towards industrial gas use, as evidenced by the 2007 and 2012 policies (Farina & Wang 2013).

Figure 6.23 Industrial Gas Demand by Selected Sub-sectors, 1991-2011



Source: CEIC (2014)

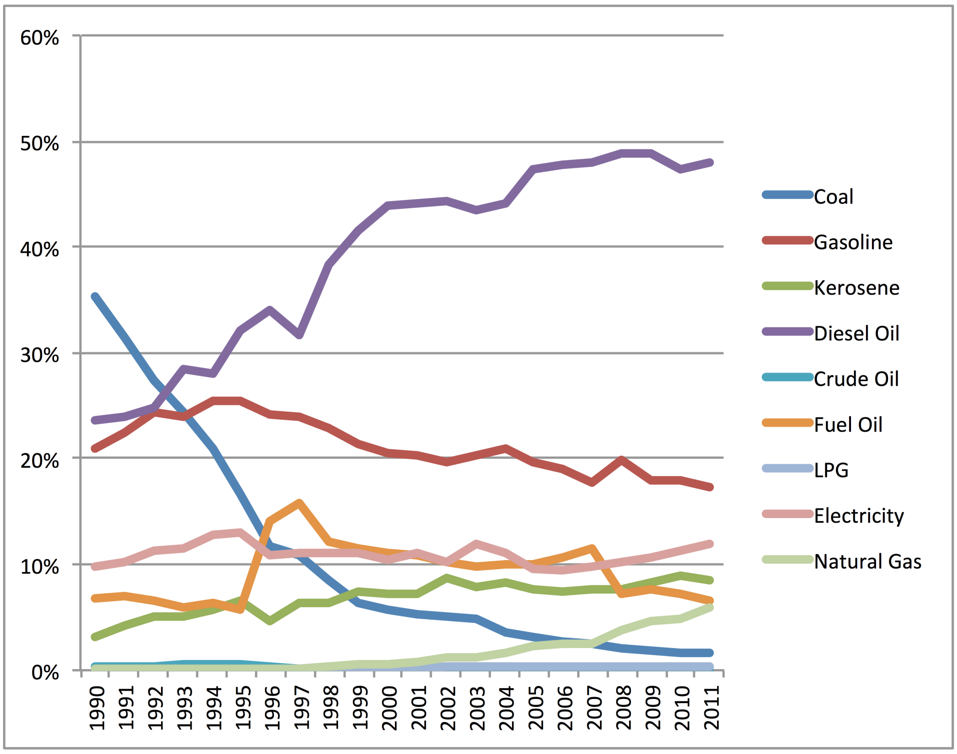
In the winter of 2013, China's gas producers were instructed by the NDRC to cut supplies to industrial consumers in order to make sure that homes and users of transport were not left short as demand surged over the winter. China has also sought to use gas supply restrictions and price rises imposed on non-residential gas use (mainly industry) in 2013 to curb overcapacity in sectors such as glassmaking, fertilisers and porcelain. Affected plants either needed to close for three months, purchase inland LNG/CNG at double prices, or switch to other gaseous fuels such as LPG (Reuters 2013).

6.5. Transport Gas Use

6.5.1. New Market

The transport sector used to provide a captive market for oil products, which now account for more than 90 percent of its fuel mix (Leung 2010). Given the rapid dieselization of the vehicle fleet, diesel alone represents almost half of the total transport energy demand in China (Leung et al. 2012). In recent years, China has considered turning natural gas into a transport fuel in order to reduce oil consumption, mitigate energy security risk and improve urban air quality. The updated Natural Gas Utilisation Policy issued by the NDRC in December 2012 for the first time "prioritises" natural gas-fuelled vehicles and vessels. One can reasonably assume that the NOCs, especially CNPC, are at least partly responsible for such a policy shift due to their vested interest, network and influence. NOCs currently face rising losses as a result of the difference in price between imports via LNG/Central Asia pipeline (2 yuan/cm for Central Asia pipeline gas, 3 yuan/cm for Qatar LNG) and regulated wholesale pipeline gas prices (less than 2 yuan/cm nationwide). NOCs have, therefore, come up with two solutions: entry to the more profitable downstream markets (as analysed in the last chapter) and promotion of natural gas as a transport fuel in the form of CNG or LNG given their much higher end-user prices. The share of natural gas in the transport fuel mix grew from less than 0.1 percent in 1990 to 6 percent in 2011 (Figure 6.24). Overall the transport sector represented 12 percent of end-use gas consumption in 2011, up from less than 0.1 percent in 1990 (CEIC 2014).

Figure 6.24 Transport Fuel Mix, 1990-2011



Source: CEIC (2014)

The room for growth in road transport energy consumption in China is enormous. Although China overtook the United States to possess the biggest stock of vehicles in 2010, the 2010 passenger car stock per capita in China was only 45.7 per 1000 persons. Put differently, on a per capita basis, China's passenger car stock in 2010 is equivalent to that of the United States in 1917, which stood at 45.8 per 1000 persons (Leung et al. 2012, pp.362-363). The small vehicle stock relative to future growth means that sunk costs are still small and that promotion of NGV would be more effective. This also means that the effect of NGV on oil demand destruction could be significant; my informant from NDRC judged that NGV will significantly reduce transport oil demand (Interview 23). China launched NGV development programmes as early as 1998 through the introduction of CNG vehicle technology from New Zealand. China launched a program called "Clean Vehicle Action of Air Purification Engineering" to promote the demonstration of CNG vehicles in 12 cities, which was expanded to 19 cities in 2005. In 1999, the number of NGV was only 2000 (Ma et al. 2013, p.543), but it reached a million in 2011, making China the world's sixth largest NGV country (Table 6.2). China has developed an entire CNG vehicle supply chain, which can produce most of the devices required by CNG vehicles and the required filling stations: In 2007, for example, eighteen companies were engaged in CNG vehicle production (Guang & Shuhui 2008). However, it remains an infant industry: the NGV penetration rate was only 1.36% in 2011, well below Pakistan's 63.3 percent and Argentina's 15.32 percent, but higher than the US's 0.05 percent (Standard Chartered 2012a).

Table 6.2 Global Top 10 NGV Countries, 2011

	No. of NGV	**NGV Penetration Rate**	**No. of NGV Refuelling Stations**
Iran	**2859386**	**14.48%**	**1820**
Pakistan	2850500	63.60%	3300
Argentina	1900000	15.32%	1902
Brazil	1694278	3.46%	1719
India	1100000	1.35%	724
China	**1000000**	**1.36%**	**2120**
Italy	779090	1.68%	858
Ukraine	390000	5.08%	324
Colombia	348747	7.10%	651
Thailand	300581	1.22%	458

Source: Standard Chartered (2012a)

6.5.2. CNG Vehicles

CNG vehicles enjoy advantages of significantly lower greenhouse gas (GHG) emissions and air pollutants, compared with gasoline (Table 6.3). When burnt, CNG produces 71 percent of GHG emission and 0.5 percent of particulate matter compared with gasoline.CNG vehicles also enjoy lower fuel costs: referring to an investigation of the CNG price and the gasoline price in nine Chinese cities in 2009, the CNG price per cubic meter was only 36.4–59.8 percent of the gasoline price per litre, while the mileage per cubic meter of CNG was approximately the same as that per litre of gasoline (Zhou et al. 2010).

Table 6.3 Comparison with Competing Transport Fuels

	CNG	**LNG**	**LPG**	**Gasoline**
Energy Density ratio to Gasoline	0.250	0.810	0.740	1.000
Carbon emission	0.710	0.760	0.810	1.000
PM	0.005	0.005	5.000	1.000
Pressure in Tank (Mpa)	17.3-24.9	0.05-1.7	0.31-1.3	Ambient

Source: Standard Chartered (2012a)

Application of CNG vehicles is not without challenges. First, since the energy density of CNG and is only 25 percent of gasoline, CNG vehicles have only around 150 km mileage given their limited storage capacity and tend to be of light-duty nature. Second, construction of CNG fill stations is both capital intensive and land intensive. To build a standard CNG filling station in China, with a capacity of supplying 15000–20000 cubic metres of CNG per day, requires an investment of approximately 2.2 million US dollars (2009 price) and a land area of 3000 square metres. Moreover, for safety reasons, a station should be kept 20-100 metres from buildings. Therefore, it is difficult to build CNG filling stations in a high-density urban area (Ma et al. 2013).

Currently, over half of the CNG vehicles are concentrated in sixteen provinces, especially the gas-rich regions including Sichuan, Chongqing, Xinjiang and Shaanxi. An investigation of the geographical difference between Chongqing and Shanghai helps shed light on the adoption of CNG vehicles (Figure 6.25). In Chongqing, more than 90 percent of the buses and taxies are using CNG, including many private cars, and its total CNG vehicles stock exceeded 40,000 in 2007. Reasons for the widespread popularisation of CNG vehicles are fourfold. First, Chongqing is the country's largest CNG vehicle manufacturing centre, occupying 30 percent of domestic market share; therefore, the price of CNG vehicles are lower. Second, Chongqing sits on the gas-abundant Sichuan basin and end-user gas prices are among the lowest nationally. Third, CNG filling stations are relatively adequately built. Fourth, strong policy support from the local government exists. For example, a leading group has been formed by sixteen departments, enacted favourable policies and supported research and development. On the other hand, Shanghai had only 281 CNG buses in 2006, or 1.6 percent of its bus population, and only four CNG filling stations. The reasons for the slow development are also fourfold: First, the CNG buses are imported and thus more expensive than ordinary locally produced diesel buses. Second, end-user gas prices are among the country's highest. Third, the CNG filling stations are few and far from downtown. Fourth, local government support is insufficient, as its only support is a one-time 80,000 RMB subsidy for the purchase of each CNG bus (Ma et al. 2013).

Figure 6.25 Locations of Chongqing and Shanghai

Source: The Author

6.5.3. LNG Vehicles

LNG has a higher energy content than CNG: a cubic metre of LNG is 2.5 times as dense than CNG under 20 MPa pressure, and the energy density of LNG is over three times higher than CNG. The subsequent advantages of LNG vehicles over CNG are the greatly improved mileage, the reduced refueling times (4 minutes compared with CNG vehicles' 15 minutes), and the reduced size and weight of the vehicle fuel supply system because the volume of LNG per unit weight is only 1/3 that of the CNG. For example, a LNG bus used in Beijing with a fuel tank containing 135 kg of LNG (i.e. 190 cubic metres of gas) can travel 450 km after one refueling (Ma et al. 2013). A LNG heavy-duty truck in the North America can travel 800 km after one refueling (Zhou et al. 2010). Besides, the investment and land use of an LNG station are less than those of a CNG station. Currently in China, an LNG filling station occupies only 800–1000 squared metres of land (i.e. three times less the CNG requirements), and the investment is 1.2–1.5 million US dollars, with a supply capacity of 12000–24000 thousand cubic metres of natural gas per day (Ma et al. 2013). The LNG supply chain is also organsiationally more flexible: unlike CNG, the LNG logistics system does not have to depend on the natural gas pipeline system, meaning that LNG filling stations are more penetrating. But given the more advanced technology needed, LNG vehicles are even less common than CNG ones. There were less than 500 LNG buses operating in 2009, and they were concentrated in Guiyang (290 buses), Zhengzhou (70), Beijing (50) and Fuzhou (39), among others.

A Bank of China report holds that the LNG vehicles will be first adopted in heavy-duty road transport, particularly heavy-duty trucks and buses, because their routes are more stable and thus spatial planning and construction of LNG filling stations network are easier (Lau 2013). In other words, LNG vehicles represent a huge potential market of NGV: whereas the two-decade development of CNG vehicles failed to significantly replace heavy-duty trucks and buses, given that the low energy-density CNG cannot replace the diesel these vehicles consume, LNG does not encounter such a technical difficulty. Even considering energy efficiency, a cubic metre of LNG is equivalent to 0.80-0.86 litre of diesel in road transport (Lau 2013).

Moreover, LNG vehicles make economical sense. A brand new LNG vehicle is about 50000-80000 RMB, or 15-30 percent, more expensive than ordinary diesel vehicle, depending on a single or dual-tank system (Lau 2013, p.6). The retrofit of current diesel engines to LNG engines costs about 65000-100000 RMB, depending on the size of the vehicle. Taking into account the fuel cost saving and assuming that LNG price is 70 percent of diesel's, the payback periods for buses, passenger cars and heavy-duty trucks are as short as 2.78 years, 1.94 years and 1.22 years, respectively. If the LNG price is only 60 percent of diesel's, the payback periods will be shortened to 1.39 years, 1.18 years and 0.70 year, respectively (Lau 2013, pp.6-7). Given their longer operating milages and larger potential fuel cost saving, commercial-use trucks and buses will be first retrofitted.

It also makes economical sense to NOCs, the only gas suppliers in China, as selling LNG is significantly more profitable than pipeline gas, regardless of the gas sources. Take Hangzhou as an example. Hangzhou is the capital of Zhejiang province and is one of the country's largest metropolitan areas. CNPC supplies gas to Hangzhou from domestic sources, Central Asia pipeline gas and imported LNG. While total gas costs vary widely from 1.60 RMB/cubic metre to 4.24 RMB/cubic metre, the city-gate price is fixed at 1.85 RMB/cubic metre by the Zhejiang government (Table 6.4). This means that CNPC suffers losses as long as it sell gas from Central Asia or LNG imports to the residents in Hangzhou.

Table 6.4 CNPC's Gas Sales Profiles in Hangzhou by Source, 2013

	Xinjiang	**Central Asia**	**Imported LNG**
Ex-plant Price/ Boarder Price	0.79 RMB/m^3	2.25 RMB/m^3	3.79 RMB/m^3
Process Cost			0.31 RMB/m^3
Transmission Cost	0.81 RMB/m^3	1.08 RMB/m^3	0.14 RMB/m^3
Total Cost	**1.60 RMB/m^3**	**3.33 RMB/m^3**	**4.24 RMB/m^3**
City-gate Price	1.85 RMB/m^3	1.85 RMB/m^3	1.85 RMB/m^3
Profit/Losses	**0.25 RMB/m^3**	**-1.48 RMB/m^3**	**-2.39 RMB/m^3**

Source: Lau (2013, p.10)

However, if CNPC sells gas in the form of LNG, it makes a profit regardless of the gas sources. Consequently CNPC's Kunlun Energy has a network of inland small-scale LNG plants. If Kunlun Energy liquefies the pipeline gas from Xinjiang using its LNG plants in Ansai, Shaanxi, transport the domestically produced LNG to Hangzhou via road transport (at a cost of 0.75 RMB per km), it still makes a profit up to 1.79 RMB/cubic metre (assuming LNG price is 70 percent of diesel). Even if CNPC uses gas from Central Asia and imported LNG, it still makes a profit up to 0.49 RMB/cubic metre and 0.75 RMB/cubic metre, respectively, instead of suffering from losses (Lau 2013, p.9).

6.5.4. City-gas Distributors

It is believed that the city-gas distributors (as discussed in previous chapter) will play a leading role in rolling out the NGV story in China. First, gas filling stations have to be set up before NGVs are adopted, and city-gas distributors, as infrastructure builders, fit the task. Second, a licence is currently required to run an NGV refueling business and local governments tend to prioritise operators that own infrastructure assets (e.g. pipelines and storage) and industry experience. Third, NGV refuelling business are expanding their market share and diversifying their porfolio from the less profitable segments, such as residential city gas supplies. Currently, the operating profit of CNG/LNG refueling stations is 3-5 percent higher than residential gas supplies (Standard Chartered 2012, p.25).

The actual NGV growth, however, varies geographically. As a result, certain distributors will benefit more with geographical exposure to the most NGV-ready regions. Four main factors determine the “NGV readiness”:

i. Demand for NGVs
ii. Availability of, or access to, gas sources
iii. Gas infrastructure, e.g. gas pipelines
iv. Better cost economics than other local fuels, e.g. LPG, gasoline and diesel

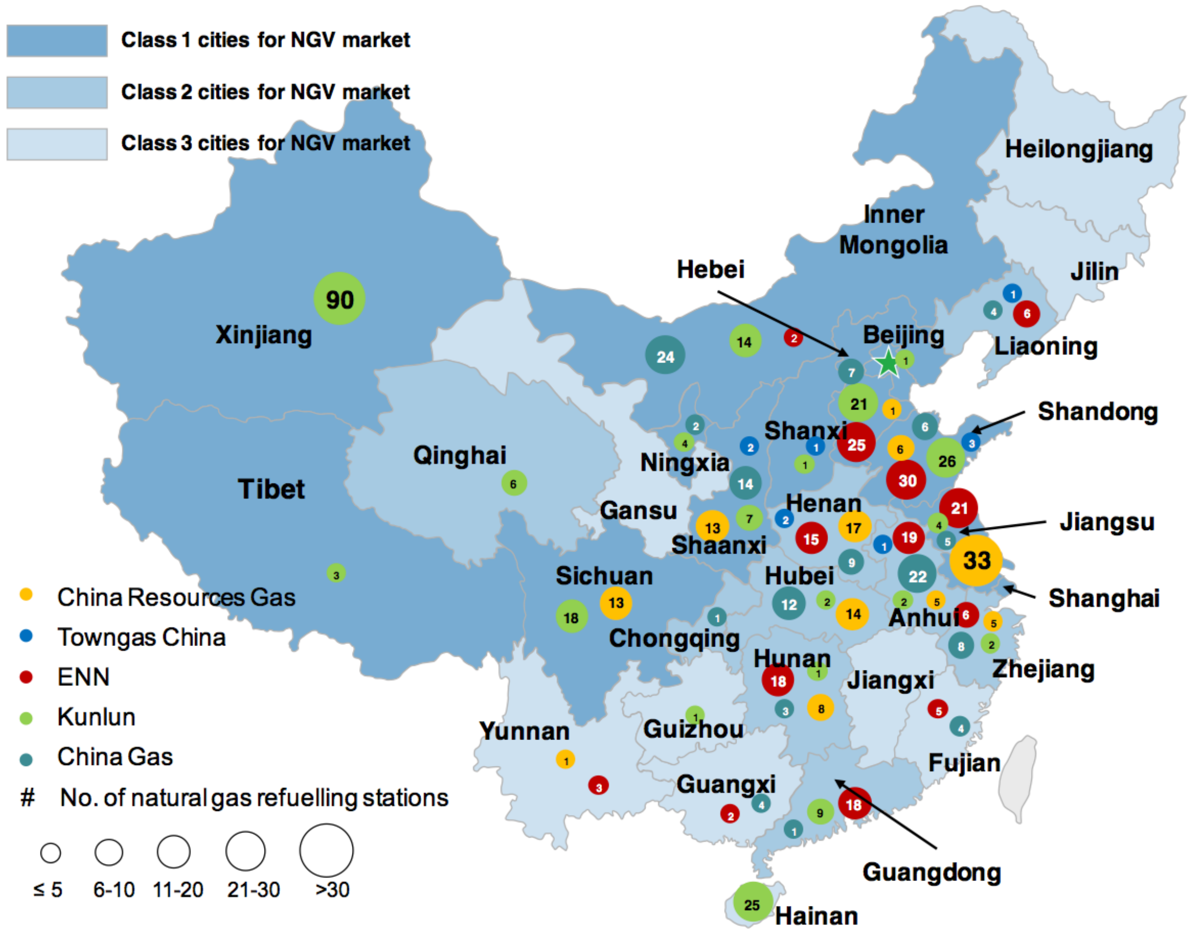
Based on the calculation in Table 6.5 factoring into the four factors, all provinces can be classified into three classes, from Class 1 (the most NGV-ready) to Class 3 (the least NGV-ready). Figure 6.26 maps the distribution of provinces by their NGV-readiness and their major presence of LNG/CNG distributors and shows that Kunlun Energy and ENN Energy will have the most benefits, given their geographical exposure to higher CV growth potential, with abundant gas supply at attractive cost economics against gasoline/diesel/LPG, while their pipeline assets are also more developed. Moreover, while CNG/LNG price is more competitive to gasoline or diesel nationwide, CNG is not much more competitive than LPG in southern China, especially Guangdong (Figure 6.27). Put differently, LPG vehicles cannot compete with NGVs outside Guangdong, as LPG is at least 20 percent more expensive in non-southern provinces. Therefore, southern China is among the least NGV ready and will continue to rely on LPG vehicles to improve urban air quality. NGV will also face little competition from electric vehicles (EVs) in the short term. The high cost of lithium-ion (LiB) batteries high cost remains the biggest barrier to the widespread adoption of EVs and their cost needs to be reduced by 50 percent to make them economically attractive without a government subsidy (RMB 120,000 maximum). This level of cost reduction will take 3-5 years to achieve while NGVs continue to grow, driven by substantial gas supply in the near term (Standard Chartered 2012).

Table 6.5 Overview of NGV Readiness by Province

			Factor 1 - Demand for NGV					Factor 2 - Gas supply			Factor 3 - Gas transport infrastructure				Factor 4 - Conversion economics				
	Province	Total score	No. of CVs in 2010 ('000)	Rank	Coal production in 2009 ('000 tons)	Rank	Score	Gas available for total consumption (cm/vehicle)	Rank	Score	Pipeline length (m)	Rank	Accessibility to LNG receiving terminals	Score	Unit cost saved for CNG (RMB/km)	Rank	Unit cost saved for LNG (RMB/km)	Rank	Score
Class 1	Xinjiang	13.53	302	16	77,795	11	1.62	6,304	3	5.00	323,469	6	N	2.03	0.33	1	1.00	9	4.88
	Shanghai	12.67	184	24	-	27	0.85	2,564	8	2.74	737,827	3	Y	4.63	0.22	17	0.97	10	4.08
	Sichuan	12.56	554	6	105,061	8	3.33	4,937	4	2.84	296,762	7	N	1.86	0.24	11	1.03	2	4.52
	Beijing	12.39	158	26	6,412	24	1.01	1,668	11	2.75	767,707	2	Y	4.82	0.20	19	0.79	13	3.63
	Shandong	12.04	914	1	148,086	5	3.99	666	21	1.68	254,420	10	Y	1.60	0.20	20	0.66	22	3.77
	Jiangsu	11.87	560	5	23,966	21	3.03	1,299	16	1.72	349,931	5	Y	2.20	0.23	13	0.67	19	3.93
	Shaanxi	11.62	287	18	285,761	3	2.08	3,015	7	3.81	184,363	12	N	1.16	0.25	8	1.01	7	4.57
	Shanxi	11.59	390	12	588,153	2	2.35	1,167	18	4.02	95,422	25	N	0.60	0.25	6	1.05	1	4.61
	Ningxia	11.55	106	27	54,979	15	0.53	3,727	6	4.82	379,264	4	N	2.38	0.21	18	0.66	23	3.82
	Tianjin	11.19	85	28	-	27	0.40	1,451	14	1.89	796,415	1	Y	5.00	0.23	12	0.66	23	3.89
	Hebei	11.16	807	4	88,825	9	3.44	598	23	1.41	112,623	22	Y	0.71	0.26	4	1.01	8	4.61
	Inner Mongolia	10.92	293	17	616,889	1	2.30	2,412	9	3.30	117,838	20	N	0.74	0.25	7	1.01	6	4.58
Class 2	Qinghai	10.57	69	29	12,837	22	0.34	7,662	1	4.34	146,160	17	N	0.92	0.32	2	1.02	4	4.97
	Zhejiang	10.53	508	8	133	26	2.72	587	24	1.27	255,581	9	Y	1.60	0.23	13	0.68	18	3.94
	Henan	10.24	838	3	235,480	4	4.09	1,180	17	1.39	126,910	19	N	0.80	0.24	10	0.67	21	3.96
	Anhui	10.04	473	9	128,548	7	2.55	574	25	1.85	164,264	14	N	1.03	0.25	5	1.02	3	4.61
	Guangdong	9.79	903	2	-	27	3.64	785	20	1.42	101,696	24	Y	0.64	0.17	27	0.70	15	3.09
	Liaoning	9.71	552	7	66,423	12	2.19	642	22	1.24	168,941	13	Y	1.06	0.22	15	0.88	12	4.22
	Chongqing	9.57	266	19	43,230	17	1.38	4,936	5	2.83	286,099	8	N	1.80	0.20	21	0.79	14	3.56
	Hubei	9.47	347	14	10,393	23	2.17	943	19	2.30	197,482	11	N	1.24	0.20	22	0.67	20	3.76
	Hunan	9.17	404	11	65,700	13	2.44	533	26	1.64	108,808	23	N	0.68	0.24	9	0.90	11	4.40
Class 3	Gansu	8.56	181	25	38,756	18	0.98	1,671	10	2.48	35,082	28	N	0.22	0.31	3	1.01	5	4.87
	Fujian	7.81	228	22	24,733	20	1.37	1,477	13	1.55	115,486	21	Y	0.73	0.18	23	0.55	27	3.17
	Heilongjiang	7.08	384	13	87,493	10	1.68	1,535	12	0.53	157,342	15	N	0.99	0.22	15	0.66	23	3.88
	Yunnan	6.67	446	10	55,159	14	2.40	156	29	1.03	7,270	29	N	0.05	0.18	24	0.69	16	3.20
	Guangxi	6.61	309	15	5,207	25	1.88	112	30	1.07	85,557	26	N	0.54	0.18	26	0.51	28	3.12
	Jilin	6.46	251	21	45,386	16	1.16	1,440	15	2.43	144,637	18	N	0.91	0.13	30	0.20	30	1.96
	Hainan	5.92	53	30	-	27	0.33	7,502	2	2.19	155,805	16	N	0.98	0.15	29	0.32	29	2.42
	Jiangxi	5.86	254	20	30,642	19	1.39	279	28	1.11	71,748	27	N	0.45	0.17	28	0.58	26	2.91
	Guizhou	5.82	206	23	137,958	6	1.53	358	27	1.10	5,623	30	N	0.04	0.18	25	0.68	17	3.16

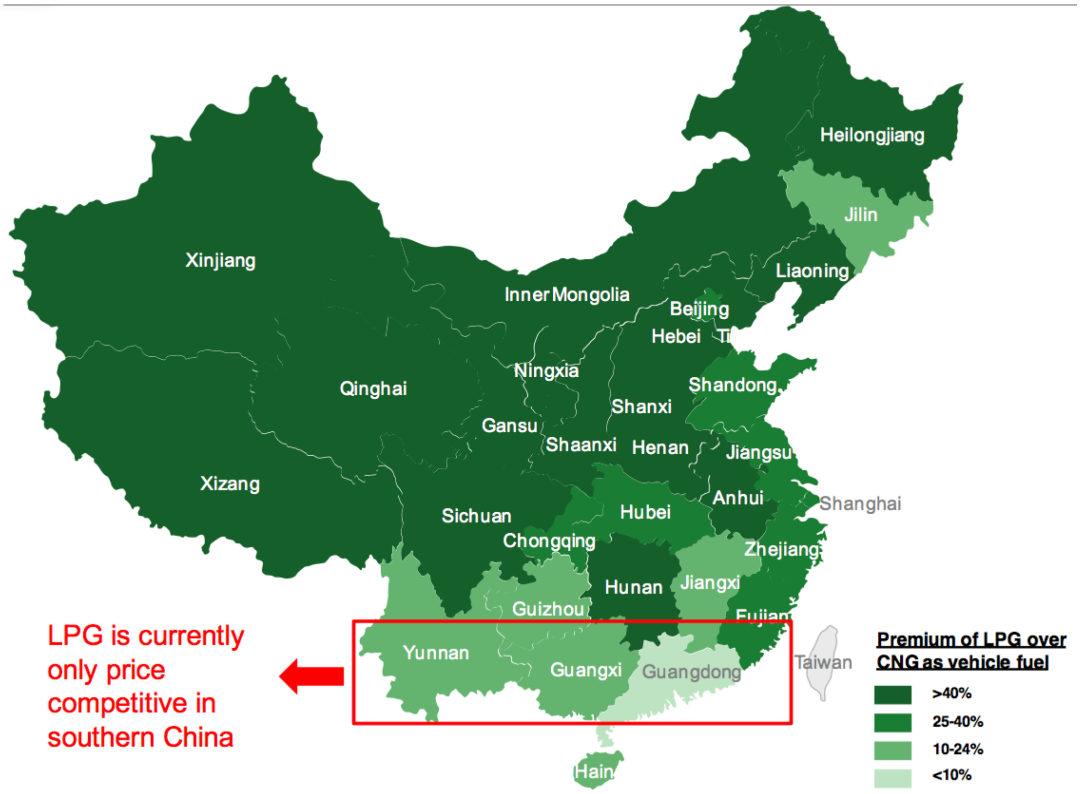
Source: Standard Chartered (2012a, p.32)

Figure 6.26 Overview of NGV Exposed Provinces with Major Presence of LNG/CNG Distributors



Source: Standard Chartered (2012a, p.11)

Figure 6.27 LPG's Price Premium to CNG, 2012



Source: Standard Chartered (2012a, p.35)

The future of transport gas use appears to be bright. LNG-powered vessels will also be commercialised in the near term. However, the gas story in the transport sector is not without challenges. The lack of a fully developed network of CNG/LNG filling stations remains a major obstacle to a more rapid popularisation of NGVs. The central government might also be concerned about the diversion of too large a proportion of gas to the transport sector and away from even higher-priority residential end-use, as gas shortage in the residential sector has the most immediate impact on citizens. Finally, the discourse that natural gas has been undervalued is becoming increasingly popular, and some local governments are beginning to enforce regulations that require the sale prices of CNG and LNG used in motor vehicles to be fixed at a level no lower than 75 percent of gasoline. Hence it remains to be seen to what extent natural gas will become more than a niche fuel for the transport sector (U.S. Environmental Protection Agency 2012).

6.6. Residential Gas Use

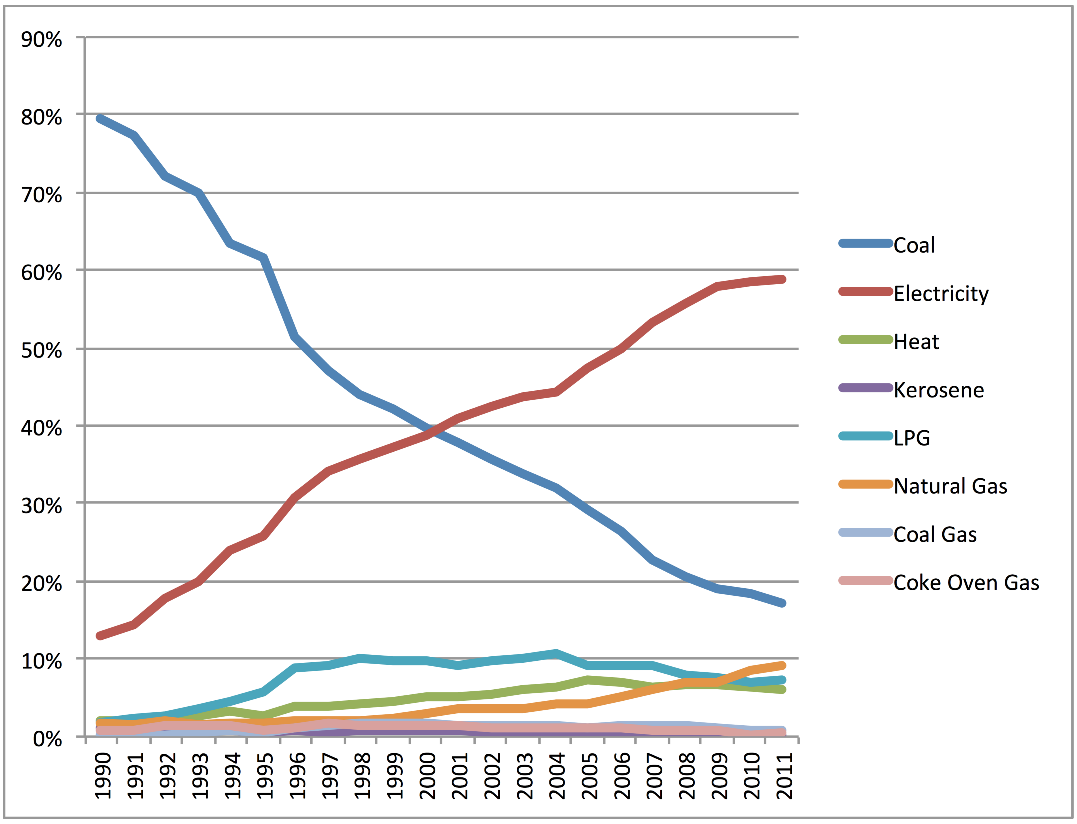
6.6.1. Moving up the Ladder

There has been a dramatic energy transition in the residential sector. An "energy ladder" concept was introduced in the 1980s in order to theorise the transition of the residential sector (mainly in the developing world) from using traditional energy carriers for their energy service needs to using more "modern", technologically sophisticated energy carriers to meet those needs (Hosier 2004). Although the concept is too linear, rigid and "modernist" (as discussed in Chapter 2), it provides a useful framework for conceptualising the overall picture. Investigating the Hong Kong gaseous fuel markets, (Chow 2001) adopted the "energy ladder" framework (he called it "household energy transition") and concluded that, in broad terms, fuel selection in this sector is determined by five factors:

i. Availability
ii. Cleanliness
iii. Convenience
iv. Price
v. Capital inertia

The dominant trends in the residential energy transition are the dramatic reduction in the importance of coal and rapid electrification (Figure 6.28; note that it is based on official data, which omits non-commercial traditional fuels: it is reported that China's traditional biomass energy demand is even higher than the total reported energy use in this sector (Leung 2010)). The share of coal in the fuel mix fell from 80 percent to 19 percent during 1990-2011, whereas that of electricity rocketed from 13 percent to 59 percent. In Hong Kong, kerosene used to serve as a bridging fuel between solid fuels (coal and fuelwood) and gaseous fuels as well as electricity when it comes to cooking and water heating (Chow 2001). In Mainland China, while kerosene was traditionally used for lighting, cooking and as a water heating fuel, it has never played a significant role in the residential fuel mix, because of the successful rural electrification programme (as a poverty alleviation measure) since the 1980s, providing an opportunity for residents to jump from solid fuels to lighting (International Energy Agency 2004).

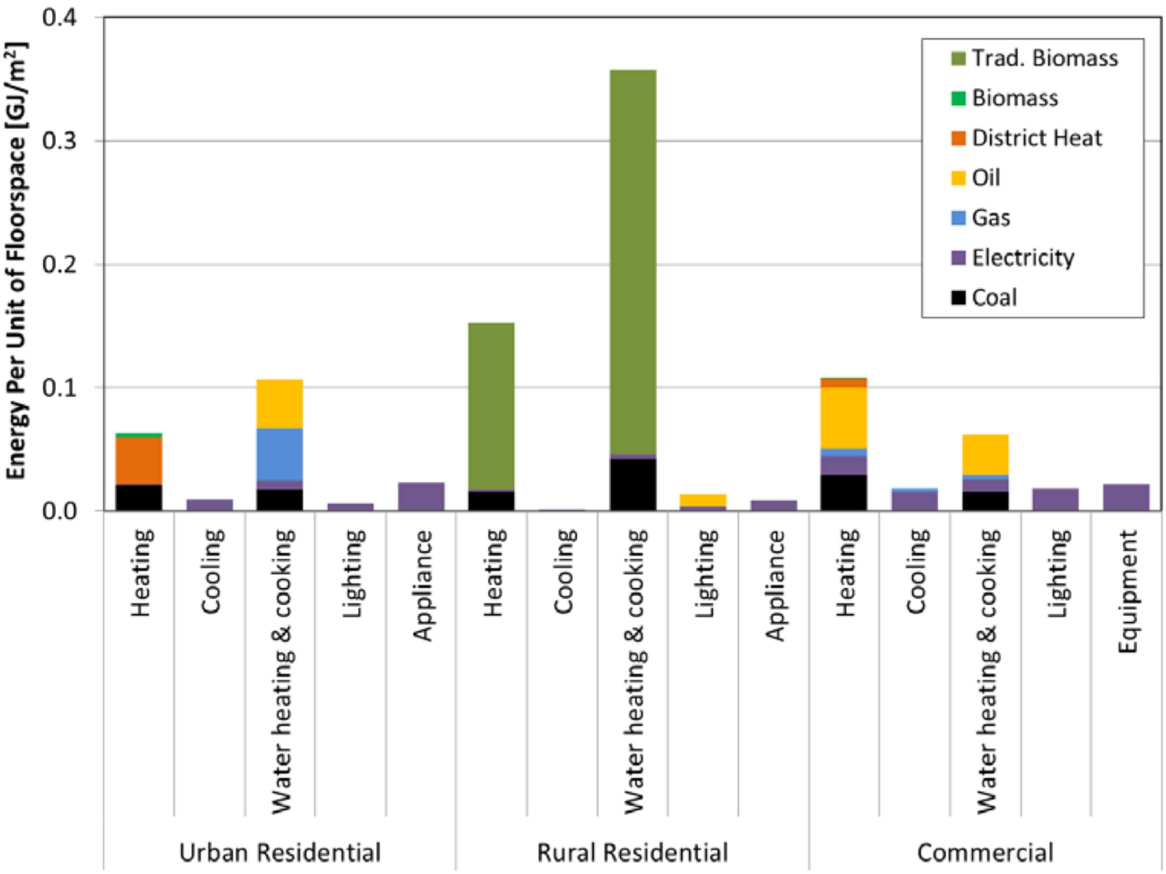
Figure 6.28 Residential Fuel Mix, 1990-2011



Source: CEIC (2014)

Gaseous fuels, including LPG, manufactured coal gas and natural gas emerged in the 1990s. The share of gaseous fuel users in total urban population rose from 21 percent in 1990 to 55 percent in 2011 (CEIC 2014). China does not publish official statistics of end-user energy services, but discontinued unofficial estimates are available. Figure 6.29 breaks down the residential sector by urban/rural area, fuel, and energy services. Although it is not true that gaseous fuels are only used by urban residents— bottled-LPG overcomes the problem of the lack of pipeline network in the rural areas and is used by rural residents (Leung 2010) — it is true that urban dwellers are the dominant consumers given their income level and the availability of the fuels. The figure also shows that gaseous fuels are used only for cooking and water heating in the cities. The share of electricity for these energy services is relatively small, in part because of the Chinese flame-cooking culture (Chow 2001). The figure also invalidates all the forecasts of China's residential gas demand based on weather, as gas is currently not used for home heating directly (but via power and heat plants).

Figure 6.29 China's Building Energy Use Density by Service and Fuel in 2005

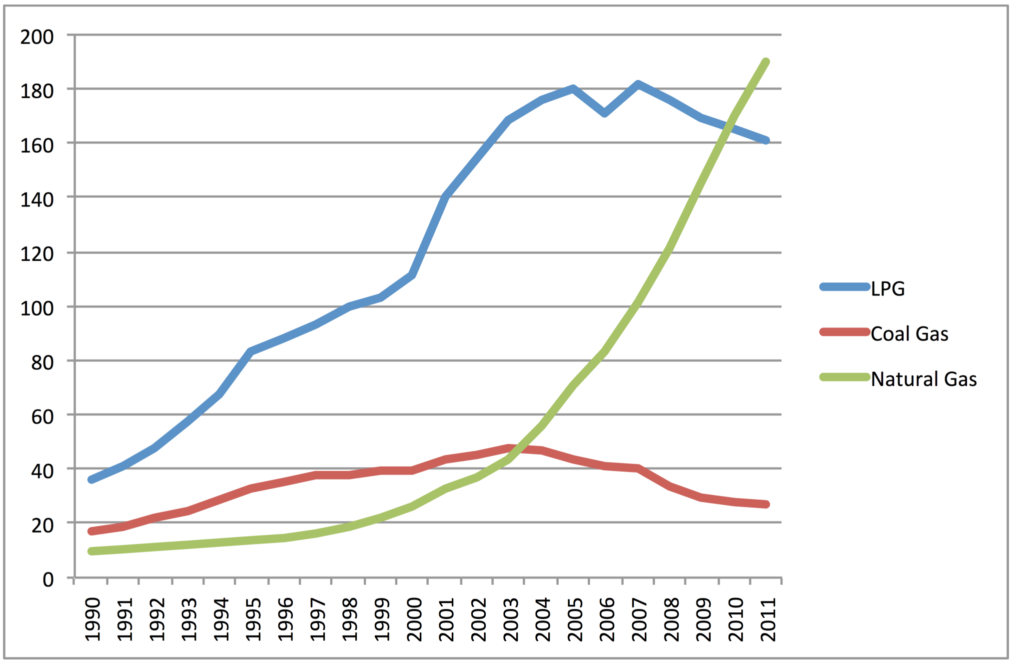


Source: Eom et al. (2012, p.5)

6.6.2. Competition of Gaseous Fuels

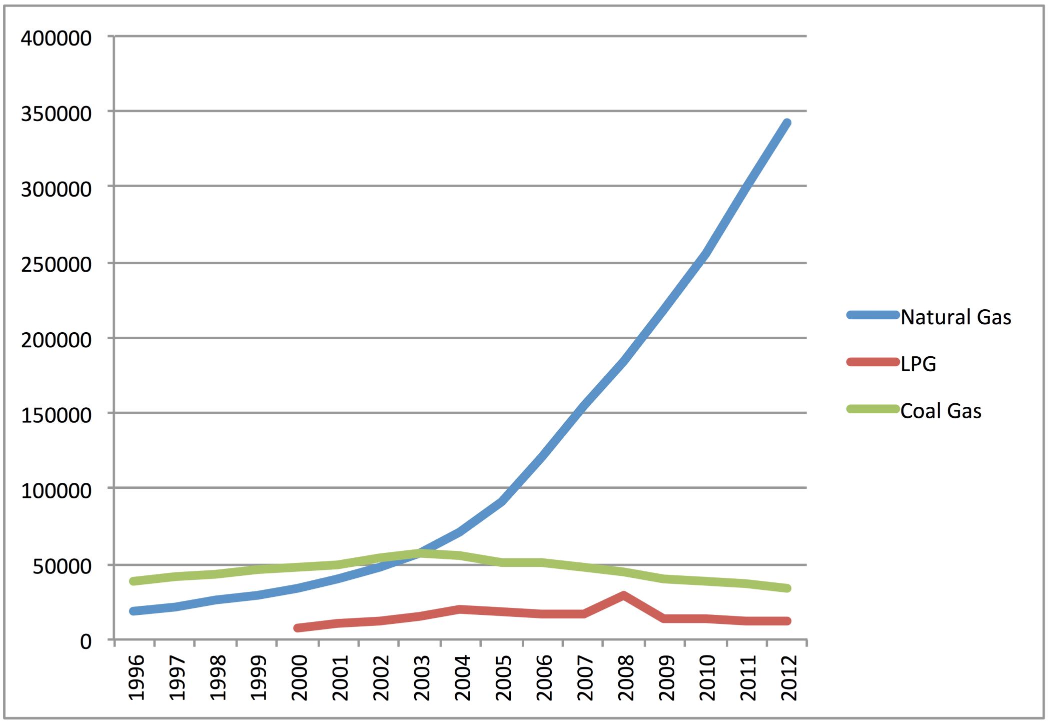
Since only urban citizens use natural gas, the following analysis pays attention to the cities. Figure 6.30 shows that the number of urban residents using coal gas dropped around 2004, when the WEGP began operating, and those using LPG peaked in 2005. The gradual reduction in coal gas is due to the lack of a coal gas pipeline network (Figure 6.31) and the fact that heat from coal gas is weaker and less concentrated than natural gas, making it a less convenient fuel for cooking and water heating. Since the energy density of natural gas is 2.5 times that of coal gas, a user in Shanghai reflected that it took him about 10 minutes to boil a pot of water when using coal gas, but only about 4 minutes when using natural gas (Zhao 2014). The reasons for the LPG-natural gas switch are that the natural gas pipeline network is denser and natural gas is significantly cheaper than LPG. Unlike the transport sector, residential natural gas end-user prices are set significantly lower than LPG nationwide, even in southern China (Figure 6.32).

Figure 6.30 Urban Population Using Gaseous Fuel by Type, 1990-2011 (million persons)



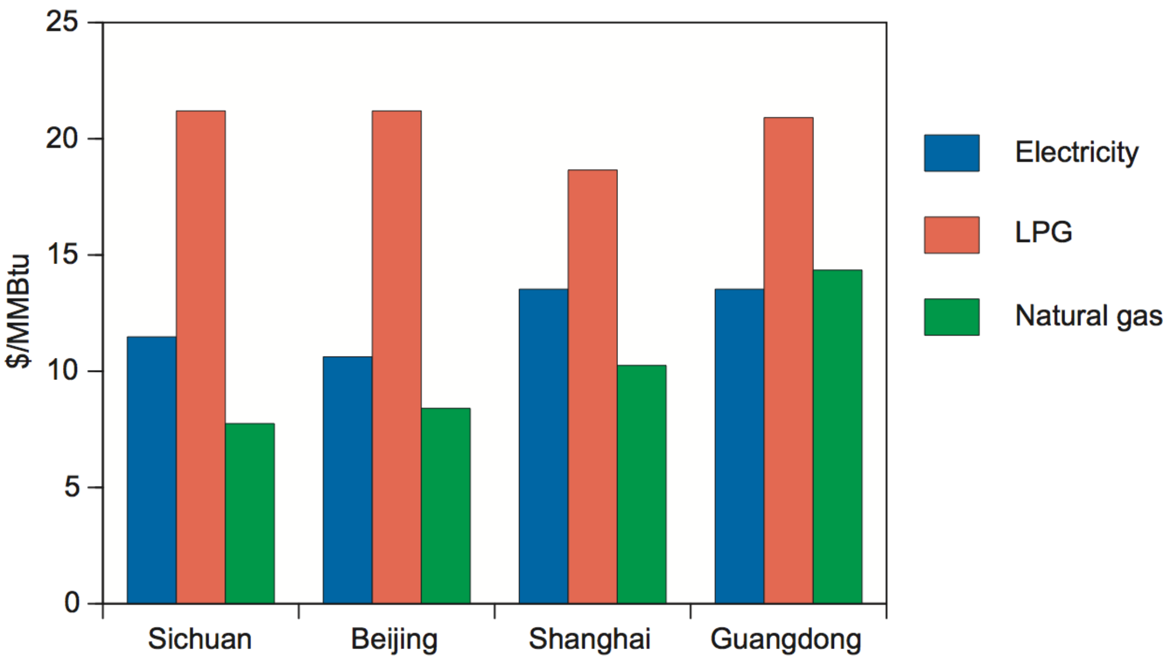
Source: CEIC (2014)

Figure 6.31 Length of Pipeline by Type, 1996-2012 (km)



Source: CEIC (2014)

Figure 6.32 Residential End-user Prices in Selected Regions, 2011



Source: Chen (2012)

Overall, residential gas use skyrocketed from 2 Bcm in 1990 to 26 Bcm in 2011, the share of gas in the residential fuel mix climbed from 2 percent to 9 percent in the same period, and the share of residential sector in total end-use gas demand doubled from 13 to 26 percent. Given the strong policy support, increasing gas supplies and development of city-gas distributors, residential gas use will continue to be driving factor of total gas demand. It is especially true when considering the fact that the gas demand in the sector is still over-concentrated in Sichuan (Figure 6.33), meaning that the room for gas demand growth is geographically widespread.

Figure 6.33 Residential Gas Demand by Province, 2011

Source: CEIC (2014)

6.7. Conclusion

This chapter has looked into the pattern of, and factors involved in, geographical and sectoral gas consumption in China. China's gas consumption grew significantly faster in the first decade of the 21st century. During the last decade, national gas consumption has proliferated not only volumetrically but also geographically. Although the per capita consumption of gas still lags behind the level in major gas consuming countries, the absolute gas demands in many Chinese provinces are now comparable to the national gas demands in a range of countries, because of the much larger population size of China. The chapter has considered different estimates of China's future gas demand and made sense of the high uncertainty surrounding China's gas market, subject to government planning on priority of natural gas consumption, gas pricing, environmental regulation, infrastructure, domestic supplies, and imports. It finds that, while the previous chapters have discussed the organisational, institutional, technological and material factors that will determine absolute future gas supplies, it is largely government gas consumption policy, city gas policy and sectoral pricing that will shape the future pattern of sectoral consumption growth.

The chapter began the sectoral analysis by investigating the power sector. It is believed that the power sector is the key to China's official gasification plan, as the role of gas is the most limited in this sector with great potential for expansion. Due to the limited supplies of gas, the central government still confines gas-fired power generation to the use of peak-load electricity shaving. Not only does gas not provide baseload electricity supplies, but it does not even provide backup services for renewable power generation either. The use of gas-fired generation as a peak-shaving measure is also largely confined to coastal areas, where affordability, emission standards and electricity demand are high. Since gas power plants cannot even meet incremental power needs, the sunk-cost obstacle to gas transition in the power sector, while it is often the case in advanced countries, is therefore less relevant at present, as gas transition in China does not involve the replacement of old systems. Nonetheless, the power sector is likely to be the "make or break" component of China's 2020 gasificaiton plan. Stricter emissions requirements in cities and increased availability of gas supplies and connectivity will promote gas use in the power sector; the expected upward adjustment in gas prices, however, will make gas-fired electricity less competitive.

Despite steady growth of industrial production, the dramatic decline in the share of industrial gas use in total gas use is conspicuous, resulting from the marginality of gas in the fuel mix, compared with other sectors, and the government's less favourable consumption policy. The traditional bulk gas user, fertiliser manufacturing, has been restricted more rigidly since the 2012 consumption guide. The share of industrial gas use is expected to continue to decline, and the centre of gravity for consumption will gradually shift towards those with interruptible service contracts, which means that gas supply is flexible and can be interrupted so that industrial gas use can be channelled to other sectors when gas shortages take place. That NDRC has frequently instructed gas producers to cut supplies to industrial consumers to make sure that homes and users of transport receive gas in the peak season, confirming that industrial gas consumers are less prioritised.

The effect of path dependency or sunk costs is often a major obstacle to the transport energy transition in countries where vehicle ownership per head is high and vehicle stock is saturated, such as the US. It is because promoting natural gas as a transport fuel involves (i) replacement or retrofitting of existing oil-powered vehicles, (ii) adopting NGVs as new vehicles, and construction of natural gas filling station networks. In China, however, such a spatial obstacle is less rigid in the early phase of a natural gas transition in the transport sector for three reasons. First, China's vehicle stock per head is still low, implying that the spatial lock-in problem is less severe. Second, the payback period of retrofitting existing vehicles is relatively short and is especially commercially attractive to logistics firms that provide heavy-duty truck and buses services. It is believed that the gas transition will mainly take place in these logistics firms first, which will help accelerate the process, given the simpler ownership structure. Timely construction of the infrastructure of natural gas filling stations is also more feasible for the heavy-duty trucks and buses industry, as their operating routes are more stable. This also means that the natural gas transition in private, light-duty vehicles can expect to experience the path dependency problem more seriously. Third, it is in the NOCs' interest to promote NGV and expand the natural gas filling station network. As explained in Chapter 5 and in this chapter, the NOCs, especially CNPC, are commercially motivated to strengthen their vertical integration by opening up markets in the downstream sector, from city gas businesses (e.g. Kunlun Gas) to natural gas filling stations (e.g. Kunlun Energy), and to hedge the price risk of growing gas imports by selling CNG and LNG in order to get around the pricing regulation. Since the NOCs are also the dominant operator of oil product filling stations, they can make use of the existing retail networks to sell CNG or LNG to drivers. Therefore, the transport sector will be the leading driver of gas consumption growth.

This chapter does not comprehensively study China's residential energy transition, which could easily be the basis of another dissertation entirely, nor does it seek to fully explore the place-based consumption cultures embedded in Chinese households. Based on simple statistical analysis, it assumes that Chinese households prefer natural gas to other gaseous fuels including LPG and coal gas because of its advantage of higher energy density (i.e. less heating time) and lower-than-LPG prices, as long as gas supplies are available to them. This chapter has attributed the increased penetration of city gas supplies to the expansion of regional transmission pipelines and liberalisation of the city gas supply chain in the early 2000s. City gas businesses, including those supplying residential and commercial users, are profitable and attractive to independent investors. Provincial end-user prices are set by local governments, who either operate or are participants in the city gas business with independent gas distributors, and have the incentive to make sure that prices are commercially reasonable.

Chapter 7 Conclusion

This dissertation has adopted a geographical political economy (GPE) approach to understanding China's natural gas transition, with an emphasis on the social, networked and institutional structures within which natural gas is embedded. To adopt a GPE approach to economic geography, as explained by Shepherd (2011), stresses "socionatural processes" of commodification and the socio-spatial inequalities, and thus "economic processes must be considered in relation to the biophysical, cultural and social processes with which they co-evolve" (pp. 320, 321). Inspired by this school, this dissertation has approached China's gas problems with a global production networks (GPN) perspective. It has clarified that China's official plan to engage in natural gas transition requires socio-technical transition of its energy supply chain. This implies a transition not just in the fuel mix but in production networks of actors and institutions, from upstream to downstream, and over time and space. The GPN approach has, to a large extent, proved effective as a means to unpack the multi-scalar, functional, organsiational, institutional and political connections of a variety of actors embedded in China's gas production networks, and how these connections will shape the natural gas transition in the next decade.

7.1. Empirical Contribution of a GPN Approach for Understanding China's Natural Gas Transition

The GPN approach has proved useful in enriching conceptualisation of China's natural gas transition in three specific ways. First, a GPN approach highlights the dialectical relations among "upstream", "mid-stream" and "downstream" sectors of the supply chain. The dissertation has argued that the mid-stream is more than just a bridge between upstream and downstream: it is an active facilitator of gas production and consumption, because it represents an active group of players, who have ultimately been shaping the length, connectivity, resilience, robustness, distribution and mode of gas distribution infrastructure, as well as the pricing mechanism that affects both producers and consumers. The detailed case study of the West-East Gas Pipeline has offered a partial window through which we understand how China's fragmented energy decision-making is, somewhat ironically, capable of fast-tracking large-scale regional transmission gas pipelines as long as the projects bring about rents to most actors and do not undermine vested interests. This finding has made sense of the rapid expansion of regional transmission pipelines in the 2000s, despite the disjointed governance structure of China's governmental departments with responsibility for energy and the NOCs. The pipeline boom has been responsible for growth in both E&P and gas consumption, as the former is the systematic prerequisite for the latter. However, China's mid-stream gas sector is still full of challenges: the regional pipeline network density of China still is low in relation to gas consumption levels by international standards; the monopoly of NOCs in the construction of regional pipelines means that the routes of pipelines would be less responsive to non-NOC producers and consumers; the lack of incentives for NOCs in constructing gas storage facilities undermines the robustness and resilience of gas supplies.

Second, the GPN approach is intrinsically geographical in the way that it self-consciously pays attention to trans-local dynamics, sub-national variations and discontinuous forms of territorial embeddedness. This study has discussed the uneven geographies of domestic natural gas reserves, extraction activities, gas flows, pricing mechanisms and consumption, and the implications of this spatial variation for natural gas transition along the supply chain. In the case of the mid-stream, for example, this study identifies two spatially discontinuous production networks - pipeline and small-scale LNG/CNG logistics - which are complementary to each other. The rapidly growing inland LNG/CNG logistics network, from small-scale LNG/CNG plants to road-based carriers, is offering a more dynamic, and geographically flexible, gas-delivery option to compensate for an inadequate and inflexible regional pipeline network. Moreover, the inland LNG/CNG industry is run by a larger number of independent firms, with their own production networks.

Third, the GPN approach rejects the choice of either state or firm as the primary analytical unit, and its emphasis on "network" has inspired this study to unpack the relational landscape of actors along the gas supply chain. This dissertation has accounted for the structure of China's gas supply chain and found an ascending number of players as one moves from the upstream to the downstream, meaning that the supply chain structure downstream is more competitive, fragmented and flexible than the upstream and mid-stream. The upstream, including extraction and gas importing activities, is dominated by only a relatively small players, namely the three biggest NOCs, who have the exclusive right to manage national conventional gas resources and to operate transnational gas pipelines and to import LNG. Independent gas players have a very limited presence in the upstream and they can participate in it only when the NOCs choose to outsource E&P projects to them, mainly via production-sharing contracts (PSCs). This occurs when (i) the NOCs do not have enough capacity; (ii) they do not have the technical know-how; (iii) they long for potential technology transfer from international oil companies (IOCs) and international oilfield service (OFS) firms; (iv) they want to acquire managerial know-how from foreign players to reform their own corporates; or (v) they want to establish trust and partnerships with IOCs for collaboration in regions outside China (i.e. other parts of the gas GPN).

At the downstream end, the liberalisation of the gas distribution industry in cities in the early 2000s has allowed independent firms and provincial governments to fully participate in the industry. Different from the E&P and regional pipeline industries, the presence of NOCs in this part of supply chain is less pronounced, partly because NOCs do not have the exclusive operating licenses as they do in other areas, and partly because they had no interest and experience in running downstream gas business until the creation of CNPC's Kunlun Gas as late as 2008. This part of the supply chain is also the most profitable, because they sell gas at end-user gas prices, which are set by the related provincial governments, who have the incentives to maintain profits returned by the gas distribution firms. However, the prospects of independent gas distribution firms have become increasingly uncertain, as the NOCs have started charting this area. The increasingly commercially-driven NOCs have looked for a higher degree of vertical integration, not only because of seeking to expand market shares, but also because of their realisation that the higher profit return of city gas industry can counter-balance the losses resulting from gas imports. Their entry to the downstream sector is worrisome to independent players, as the NOCs possess unmatched advantages over access to gas sources, political connections, and financial power. It is expected that the number of players in this sector will decline, as smaller firms will be gradually acquired by larger firms, as a result of more intense competition for uncharted markets.

Similarly, the concept of "strategic coupling" also encourages investigation of the interaction of state actors, institutions and firms. The research found that the regional institutions of unconventional gas are more capable of "holding down" the gas GPN of IOCs, confirming the "conditionality" of a strategic coupling between regional assets and inwardly-investing firms. This research took shale gas as a case study: here analyses of Chinese techno-nationalism suggest that the NOCs are unwilling to share their assets with foreign players unless they have to rely on foreign innovations. Exploring and developing shale gas is more technologically challenging than NOCs have been able to handle. Although the informants I interviewed claimed that NOCs do not have the incentive to produce shale gas at present, until pricing reform is introduced and shale gas production becomes profitable, they are actively researching on how to produce shale gas technologically when prices are right. IOCs that are working with NOCs in China include Shell, Chevron, Eni and ConocoPhillips, although only Shell has signed a PSC (for Fushun-Yongchuan shale gas block with CNPC, since 2012). More importantly, the Chinese government is aware of the importance of the role played by private sector innovations in the shale gas "revolution" underway in the US. To promote the participation of independent players, the government has changed the institutional status of shale gas by identifying shale gas as a mineral resource independent from natural gas, so that the NOCs would not have automatic claims to it. Furthermore, the government invited the private sector in the second round of the shale gas auction to engage in exploration independently. The winners, especially those without any experience in oil and gas E&P, would have to invite domestic and international OFS firms to help.

Strategic coupling, however, should not be understood as if the IOCs are a group of passive actors waiting for the right regional institution to "hold them down". The strategy of Shell China, revealed in my interview, suggests that some forward-looking IOCs would work with NOCs in areas that are not profitable in exchange for their collaboration in areas that are. Shell admitted that China's E&P sector, especially shale gas, is not profitable or is even "money-burning", but they need to keep NOCs and the Chinese government close, happy and friendly to them, and they need to have more positions in the supply chain to monitor the China market more "holistically". This is because, in addition to E&P, Shell is also a key LNG supplier to China and has a significant market share in oil refinery and oil products sales. A GPN perspective also echoes this holistic understanding of an energy supply chain. The dissertation has reiterated the dialectic relations between upstream, mid-stream and downstream, and each of them cannot be understood independently of the other integral components.

7.2. Limitations of a GPN Approach for Understanding Natural Gas Transition

Inspired by the GPN perspective, the analytical focus of this study is broader than traditional global commodity chain (GCC)/global value chain (GVC) studies and is focused not only on firm-firm connections, but also on firm-state as well as intra- firm relations. It confirms the insights of economic geographers that the state, despite traditionally being attacked by liberal economists, "has proved remarkably resilient and remains the principal locus of governance as well as the primary determinant of personal attachments and identity" (Rodrik 2013, p.1), and therefore the state, its sovereign boundaries and multi-scalar institutions still matter in a globalising or neo-liberalising world (Dicken 2011).

However, in practice, the GPN literature's focus on the state is either too implicit or over-simplified, failing to differentiate the different actors, sometimes mutually contradictory, of the state. This GPN research has uniquely unpacked the "black box" of "state" in China. This "intra-state" analysis is particularly vital to understanding the regional political economy of China. Although China no longer adopts a command economy, the influence of the variety of its state actors, including the state- owned enterprises (SOEs) and Chinese Communist Party (CCP), is still so penetrating and widespread that David Harvey (2005) considered China as a "strange case": a type of "neo-liberalism" combined with "authoritarian centralised control". The state tightly controls its oil and gas resources and considers them "strategic", and its influence is evident in different stages of the gas supply chain, from upstream to downstream, as well as at different scales, from local to supra-national. As a whole, the state plays the roles of landlord, grand planner, price setter, financier, diplomat and national champion in the supply chain of gas. But China is not a single-minded, coherent monolith: this study finds that, since the on-going economic reforms and bureaucratic/administrative restructuring in the post-Mao China, the Chinese administration has become fragmented both horizontally (departmentalisation of power and interests) and vertically (localisation of power and interests), with significant institutional effects across different parts of the gas supply chain.

The study has also found that the creation and commercialisation of Chinese national oil companies (NOCs) has further complicated the relational landscape. The NOCs were created in the 1980s out of government ministries, giving birth to a dominant gas player with the inheritance of virtually all national gas resources (except some unconventional gas). The establishment of their listed affiliates in the early 2000s has "re-embedded" the mentality of the NOCs, and made them more rent-seeking (sometimes at the expense of the government policy, such as liberalisation of gas distribution industry in cities) and more assertive (by actively lobbying the policy making and agenda setting through their personnel network with the senior officials). The central energy authority, such as National Energy Administration (NEA), has become politically weak and administratively under-staffed. The National Development and Reform Commission (NDRC) has also become disjointed functionally and has consequently found it difficult to speak in a unified voice. Indirectly, this development further empowers the NOCs and enhances their autonomy. But their autonomy is mostly confined to operational autonomy, and not strategic autonomy. The central leaders, especially via the Chinese Community Party networks, can still determine or adjust the NOCs' activities in areas they deem "strategic", such as gas consumption subsidy via regulated pricing, and prohibition of Sinopec's hostile takeover of China Gas, a private gas distributing company.

Moreover, the GPN approach has been criticised for not sufficiently considering the importance of "state-state" relations. This is a valid challenge to GPN, particularly in the attempt to apply the GPN approach to the oil and gas sector. Since the oil and gas sector is widely regarded as a strategic industry by every country, the consideration of classical geopolitical factors, such as realpolitik diplomacy (based primary on balance of power), territorial location, and access to transportation routes, is often unavoidable in international oil and gas transactions. This study confirms that China's official energy security discourse is constructed around a geopolitical imagination of external vulnerability that climbing oil and gas imports would create, especially in the high seas, where the US Navy has a significant presence. This imagination can also be linked to the collective recollection of China's experience of the imposition of embargoes and blockades during the Cold War. The construction of the Central Asia-China Gas Pipeline and Myanmar-China Oil and Gas Pipelines is at least partly a response to this geopolitical imagination. It remains to be seen how China's energy diplomacy will unfold if the country needs to import significantly more LNG from regions outside Asia-Pacific, such as the Middle East and East Africa.

Finally, the GPN framework is criticised for being too "productionist", as it does not currently provide sufficient analytical tools to study questions of consumption. Nonetheless it has inspired this study to be more conscious of the industry structure of each gas consuming sector, the relevance of spatial embeddedness and path dependency, and the importance of institutions to patterns of consumption. The dissertation has found that China's gas consumption is effectively shaped by the government's gas use priority policy through legal documents and differential pricing. Despite recent growth, the role of gas-fired power generation will remain small, as it is confined to some coastal regions and its application is limited to peak shaving only. It is because the government policies have given it low- priority considering insufficient supplies of gas, and because prices for gas are uncompetitive against coal. Even if gas supplies would become more abundant, as production and import capacities continue to develop, the role of gas in the power sector will likely remain limited, given that the gas demand by the prioritised sectors, such as residential and transport, will absorb the additional supplies, and that the price uncompetitiveness of gas against coal will be worsen amid the expected increase in gas prices. Since gas-fired power generation is vital to the official plans to reduce coal use and carbon emission, China's natural gas transition as a low-carbon strategy will not materialise if the government cannot find a way to dramatically enhance of the application of gas in the power sector: for example, by boosting gas supplies rapidly, forbidding coal-fired generation in cities through administrative means such as environmental regulation, or increasing the price competitiveness of gas against coal through carbon trading. The industrial sector, while remaining the largest gas consumer, will grow more slowly than other sectors, because of the more restrictive government policy on industrial gas use and the marginality of gas in the fuel mix. The transport sector will see the fastest growth in gas use in China, as it has ticked all the boxes of favourable institutional conditions, but the transition will be mostly confined to heavy-duty commercial logistics. The growth of residential and commercial gas use results primarily from the liberalisation and development of gas distribution industry in cities, and such growth will continue due to the price and functional advantages of gas over LPG and coal gas, and the increased level of urbanisation.

7.3. Future Researches

There are four important areas of China's gas transition that this study does not sufficiently investigate. First, how do international geopolitics affect China's natural gas transition, and how will they be affected by it? There are a number of potential questions here. For example, if China needs to import more gas, what are the implications for other gas importers? How has geopolitical events, such as the Ukraine crisis, facilitated the Russia-China gas deal in May 2014? How will Russia manage its gas exports to the East and West? Is it true that China will be somewhat reluctant to import American LNG for the realpolitik consideration for balance of power? To what extent has geopolitical strategy rather than energy led to the construction of the Myanmar-China oil and gas pipelines? Second, what are the prospects for unconventional gas, especially shale gas and CBM, and is the monopoly of NOCs, lack of interest, price or technology the most significant constraint? Third, how can gas demand be created sufficiently to meet the government target, particularly in the power sector? Finally, how do we understand gas transition as part of a broader low-carbon energy transition? To what extent does gas interact with renewable energies in China - to what extent, are they competing against each other in terms of investment? What is the future role for coal? Can natural gas and renewable energies not only replace incremental increases in coal consumption, but also contribute to an absolute decline? These questions have beyond the scope of this study and so remain largely unanswered by it: undoubtedly, however, they carry heavy implications and justify further investigation.

Appendix 1 Map of China

Source: Economist Intelligence Unit

Appendix 2 Interviews

Interview 1: Research Associate, European Centre for Energy and Resource Security, King's College London (22 May 2013).

Interview 2: Director, Research Department, Beijing Gas (28 April 2013).

Interview 3: Analyst, General Affairs Department, National Energy Administration (27 May 2013)

Interview 4: Analyst, Research Institute of Economics and Technology, CNPC (31 March 2013)

Interview 5: Senior Analyst, Risk Control Department, China National United Oil Corp., CNPC (5 April 2013)

Interview 6: Director, Policy Research Unit, China United Coalbed Methane Corporation (10 May 2013)

Interview 7: Vice President, Greater China Gas and LNG, Shell (24 May 2013)

Interview 8: Director, China Petroleum Institute, Schlumberger (21 May 2013)

Interview 9: Vice Director, Exploration Department, CNPC Advisory Centre (15 April 2013)

Interview 10: Analyst, Sinopec Research Institute of Petroleum Exploration & Production (26 April 2013)

Interview 11: Deputy Chief Engineer, Sino-Russian Cooperation and Project Department, CNPC (9 May 2013)

Interview 12: President (China), North West Shelf Australia LNG (20 May 2013)
Interview 13: Chief Legal Consultant, CNPC Kunlun Gas; Chairman, CNPC Kunlun Gas (Lanzhou); Deputy Party Secretary, Chinese Communist Party (19 May 2013)

Interview 14: Vice Director, China Oil and Gas Centre, Chinese Petroleum University (23 May 2013)

Interview 15: Director, Research Unit, Beijing Gas (28 April 2013)

Interview 16: Senior Vice President, Hong Kong & China Gas Investment Limited, Towngas (7 September 2012)

Interview 17: President, China Gas (27 May 2013)

Interview 18: Secretary-general, China Gas Association (1 June 2013)

Interview 19: Vice President, Beijing Gas (27 May 2013)

Interview 20: Vice Director, Energy Research Institute, National Reform and Development Commission (9 May 2013)

Interview 21: Analyst, Policy Research Unit, CNOOC (16 April 2013)

Interview 22: Senior Expert, Energy Decision-making Technology R&D Centre, State Grid (22 April 2013)

Interview 23: Director, Centre for Energy Economics and Development Strategy, National Reform and Development Commission (22 April 2013)

Interview 24: Vice President, BP China (26 April 2013)

Interview 25: Commercial Analyst, China Light Power Limited (17 July 2012)

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